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THE APPLICATIONS

OF

WIRE ROPE

TO

TRANSPORTATION

POWER TRANSMISSION, ETC.

1903

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THE

BLEICHERT SYSTEM

OF

WIRE ROPE TRAMWAYS,

WITH SPECIAL REFERENCE TO THE

Patent Locked-Coil Track Cable

AND THE

Webber Patent Automatic Grip.

No lugs required on the steepest grades.

Reversible Wire Rope Tramways,

with Self-dumping Buckets.

BY WILLIAM HEWITT, M.E.

THE TRENTON IRON COMPANY,
MANUFACTURERS,
Trenton, New Jersey, U. S. A.

1903.

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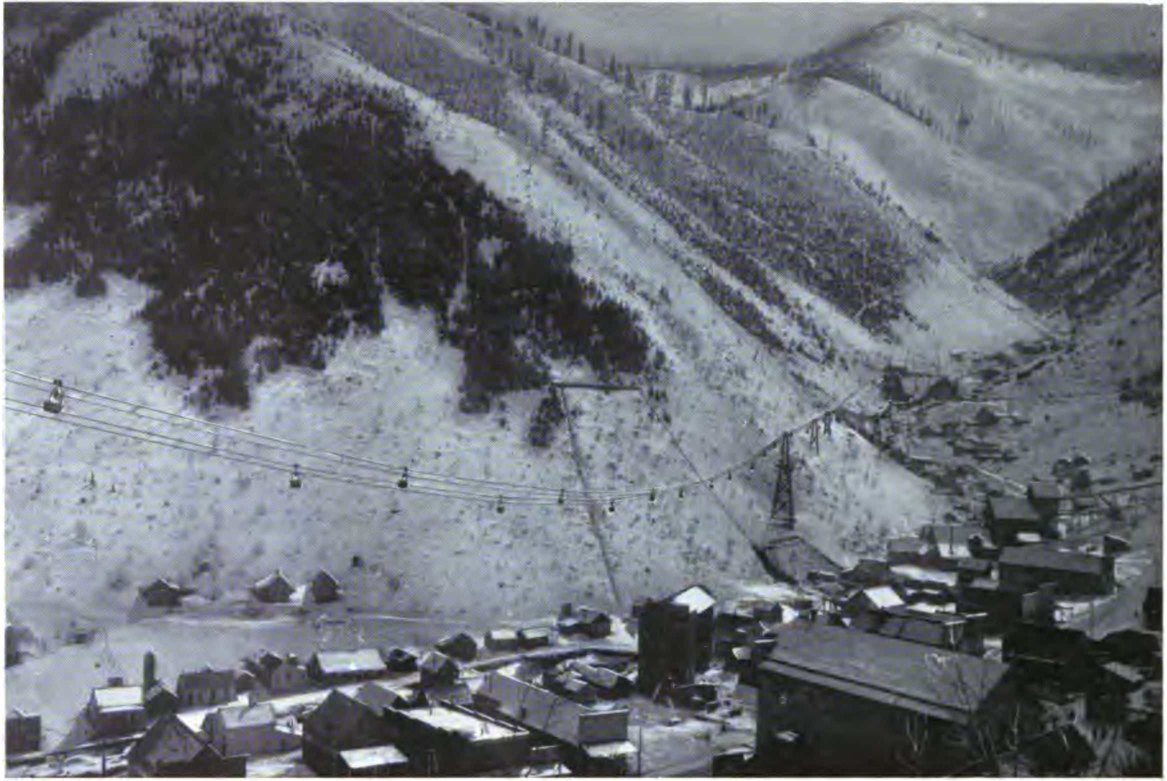

Length of line, 9,000 feet. BLEICHERT TRAMWAY, Hourly capacity, 50 tons.

Built by THE TRENTON IRON CO., Trenton, N. J.,

For the Bunker Hill and Sullivan Mining and Concentrating Co., Kellogg, Idaho, showing portion of a span of 1,173 feet, across the town of Wardner.

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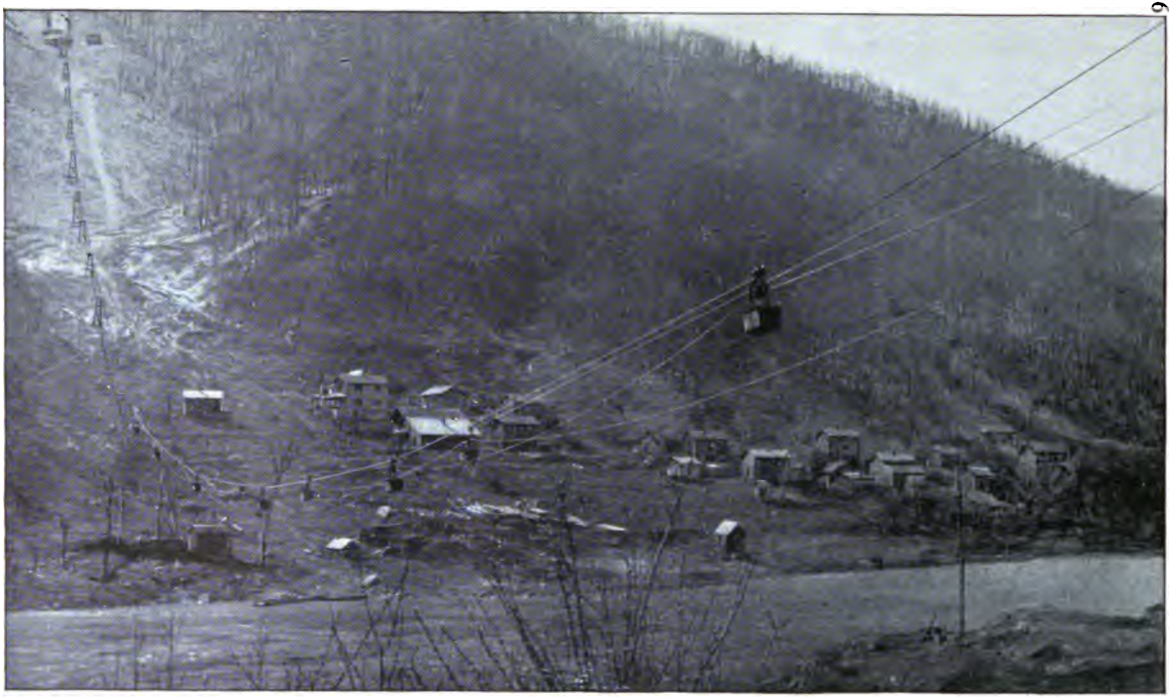
The Bleichert System of Wire Rope Tramways.

THE general distinguishing feature of the BLEICHERT SYSTEM of wire rope tramways, is the use of stationary track cables of special construction for supporting the pendant carriers, and of a comparatively light endless traction rope for moving them. It is known to many as the "Double-Rope" system, in contradistinction to the "Single-Rope" system, in which one rope performs both functions.

The Bleichert system is adapted to the transportation of all kinds of materials, under every conceivable condition, and is especially recommended for heavy service, and mountainous localities where steep grades and long spans occur. Every detail has been thoroughly worked out and proved by actual practice, and *special attention is invited in the following pages to our* PATENT LOCKED-COIL TRACK CABLE, *and the* WEBBER PATENT COMPRESSION GRIP *with* PATENT AUTOMATIC ATTACHER, the merits of which have established the superiority of the Bleichert system.

The materials used in the construction of the various parts are of the strongest and best, and the workmanship first-class in every respect. All parts of the machinery are made to standard gauges, so that repairs can be made promptly and cheaply. The general design is such as to make the action of the tramway as nearly automatic as can be, so that but little labor is required in the operation of these lines. The cars can be raised or lowered at any terminal or intermediate station by our special hoists, from one level to another, or from one floor to another, in a warehouse or factory for instance, and upon arriving at the desired elevation or floor, can be conveyed by our elevated track or shunt rails to any point for loading or unloading. Scales are furnished of special



Length of line, 2,800 feet.

BLEICHERT TRAMWAY,

Built by THE TRENTON IRON CO., Trenton, N. J.,

For the Royal Coal and Coke Co., Prince, West Va.,
showing span across New river.

Hourly capacity, 80 tons.

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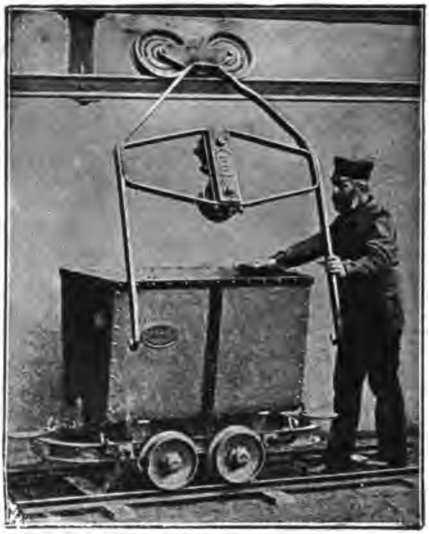
design for weighing the loaded cars, or counters, which will automatically register the number transported.

By means of specially-designed cars (see page 23), the buckets can be transferred from the shunt rails to surface tracks and taken directly to the working faces of the mine or quarry, as the case may be, brought back and sent over the line without re-handling of the material. A common method of transferring the buckets to and from surface cars, which requires no mechanical appliance, is by laying the surface rails under the terminal shunt rails, so as to form a circuit with them, and on inclinations sufficient to lift the buckets from the hangers on one side, and drop them into the hangers on the other side, as the hangers and surface cars are moved along together. An instance of this method of transferring the buckets is in the line of the Mathieson Alkali Co., at Saltville, Va. Mr. W. D. Mount, the superintendent, writes that "the system of transferring the empty buckets to the cars and the loaded buckets from the cars to the wire rope tramway again, has not been changed in the slightest detail since it was erected, and is in every way satisfactory as laid out originally. We cannot see how it could be improved and would strongly recommend it in any future installations you may put up where such an arrangement is necessary."



Transferring Bucket to Surface Car.

We are also prepared to furnish a very ingenious and reliable hydraulic regulator for controlling the speed of lines operated by gravity under control of brakes. If the speed exceeds a predetermined rate for which the machine is constructed, the governor closes the valve through which the fluid circulates to a degree sufficient to absorb the excess of power developed and maintain a uniform speed.

The Bleichert system permits of the introduction of intermediate loading stations at any point, which may be movable or permanent structures, as desired.

The illustrations and inset charts of details and profiles herein will serve to give a general idea of the various applications and adaptabilities of the system.

THE CABLES.

Ordinary wire cable composed of wire strands laid about a hemp or wire strand core is not at all adapted to the purpose of a track cable, since the traction of the carriage wheels on the uneven surface causes the rapid wear and fracturing of the comparatively small wires.

The construction of track cable that meets with the greatest favor (manufactured only by the Trenton Iron Co.) is known as the "patent locked-coil cable," from the fact that the outer wires are of such shape that they interlock, as illustrated in Fig. 1, presenting a smooth surface and yet possessing sufficient flexibility to be shipped in coils. The objection to fractures, which in other special constructions of track cables results in loose and tangled wires, is entirely obviated in the Patent Locked-Coil Cable, which gives the highest degree of service, with a minimum wear on the carriage wheels, and its superiority for this special purpose is now universally acknowledged. It is made of a select grade of steel, in lengths of from 800 to 1,200 feet, which are joined by patent couplings illustrated in Fig. 2.

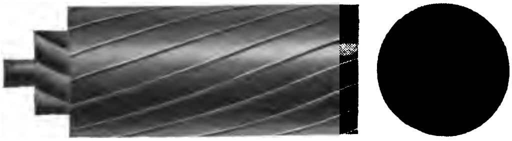


Fig. 1. Patent Locked-Coil Track Cable.

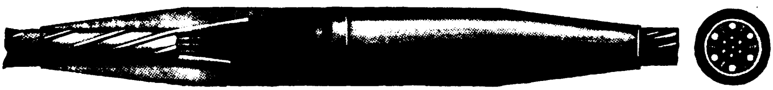


Fig. 2. Patent Coupling.

The coupling is in halves, with an opening in each, in which the rope is inserted, this opening being funnel-shaped on the inside. The ends of the wires are spread apart in the funnel, and the intervening spaces are filled with wedges and conical rings, which are made approximately to the shape of the interstices, and are driven in tightly, which binds all the wires uniformly. The halves are joined by a plug with right and left-hand screw-threads.

The track cable known as the SMOOTH-COIL CABLE, illustrated in Fig. 3, is furnished where a cheaper construction is desired. It is composed simply of a number of comparatively large round wires coiled in concentric layers about a core wire, the number of layers and size of the wires varying according to the size of the cable, which is practically a large strand, the surface of which, when new, resembles that of a spirally fluted cylinder, and when worn approximates that of a smooth round bar. It is vastly superior as a track cable to ordinary cables, owing to its smoother surface and larger wires, and with good care under favorable conditions it has given very satisfactory service.

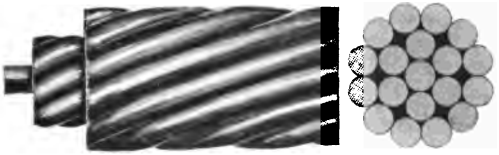


Fig. 3. Smooth-Coil Track Cable.

The track cables are graduated to the loads and pressure they have to sustain and, being stationary, possess the great advantage of relieving the traction rope of the weight of the loads, so that on comparatively level lines the tension upon the traction rope is but little more than the tractive force required to move the loads. Upon slopes, however, the weight of the loads is shared, to a certain extent, by both the track cable and traction rope, the amount borne by each depending on the inclination; the steeper the inclination the greater the weight on the traction rope and the less on the track cable, and *vice versa*. The stress upon the track cable however varies little with differences in the inclinations, since it is weighted to a maximum safe tension so that such differences result only in corresponding variations in the deflections, but the stress upon the traction rope will depend on the slope, and it is important, therefore, in estimating upon any line to know what the grades are. A further advantage derived from the use of stationary track cables is due to the high tension to which these are stretched, thus securing to the loads a comparatively direct path; in other words, they are subject to less fluctuations of rise and fall, or wave motion, than in single rope lines, since, in the latter, the deflections for similar loads must necessarily be greater to correspond with a practical safe working tension, and the double duty the rope has to perform of supporting and moving the loads, and the wear and tear therefore is very much less. For this reason, also, and owing to the greater strength of the track cables, the Bleichert system is adapted to the transportation of much heavier loads than is practicable in any kind of single-rope tramway.

Our practice is to lay out the line of the track cables very carefully for a certain safe working tension, and erect the supports to this line, the cables being actually stretched to a somewhat lower tension, so that there may be no possibility of their rising out of the saddles upon which they rest.

THE ROLLING STOCK.

The ordinary car, such as used for transporting ore and like material, is illustrated in Fig. 4. The complete car, it will be observed, consists of a carriage which runs on the track cable, a hanger depending from this which supports the bucket, and a grip, by means of which the car is attached to the traction rope. When the cars arrive at either terminal, or other station, the grips detach automatically, and the carriages are switched off on to the shunt rails, supported by the structure of the station, by means of which they are conveyed to the points of loading or discharge as the case may be.

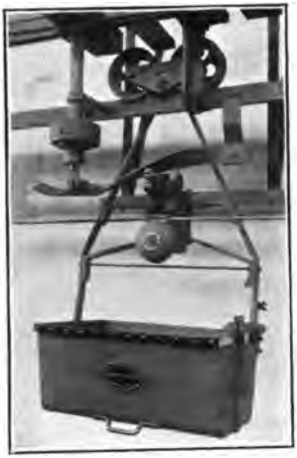


Fig. 4.
TRAMWAY CAR,
With Webber Patent Compression Grip, showing Patent Automatic Attacher.

THE WEBBER PATENT COMPRESSION GRIP *with which the cars are fitted can be used on the steepest grades. With this grip no buttons, lugs, or knots of any kind are required on the traction rope, and the troubles incident to the slipping of such contrivances are entirely avoided. A great economy is also effected in the life of the traction rope, owing to the fact that the wear is not confined to certain spots, but is distributed over the entire rope. The attachment to the traction rope is also effected with certainty and automatically by means of a patented device, shown in Fig. 4, the operation of which is such that the grip takes hold of the rope without the slightest jerk as the car is pushed out from the station.* This grip has proved so satisfactory in all the numerous lines on which it is now operated, that it has entirely superseded the old friction and lug grips formerly used.

With systems of wire rope tramways in which the carriers are permanently attached to the rope and the receptacles have to be loaded and discharged while in motion, it is necessary to resort to automatic loaders and dumpers, the use of which has led to an erroneous impression that they are economical of labor. Automatic loaders are not only unnecessary in the Bleichert system, since the cars are detached from the traction rope at the stations, and the loading and discharge of the receptacles effected while they are at rest, but they are to be avoided, as their use makes it necessary to operate at a slower speed, which requires a larger outfit of cars for a given capacity and adds to the wear of the rope.

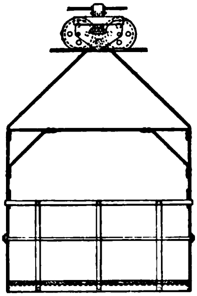


Fig. 5.

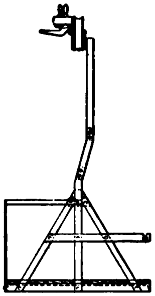


Fig. 6.

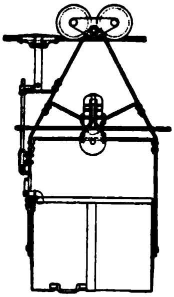


Fig. 7.

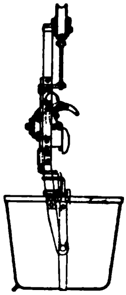


Fig. 8.

At angle stations, where there is nothing to do but pass the cars by the sheaves, it is reasonable to look for an economy of labor in the passage of the cars without detaching from the traction rope. With the ordinary tramway car however, having the grip between the carriage and the bucket, it is obvious that this is impossible, not necessarily because the grip must come in contact with the flanges of the sheaves, but because on the angle side of the bend the hangers would come between the rope and the sheaves, which would cause trouble. This difficulty is readily overcome by running the traction rope just above the track cables, and attaching the grips to the carriages, as illustrated in Figs. 5 and 6, showing style of carrier used on a line of the Plymouth Cordage Company, Plymouth, Mass., or constructing them as an integral part of the carriage mechanism, as in the car illustrated in Fig. 9, showing the latest construction of the Bleichert Patent Automatic Overhead Grip, in which the weight of the

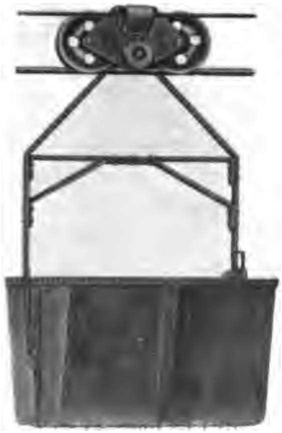


Fig. 9.
TRAMWAY CAR,
With Bleichert Patent Automatic
Overhead Grip.

car acts as the gripping force, which is therefore independent of any nice adjustment of the grip jaws. It is not always practicable however to run the traction rope above the track cables, as for instance in crossing mountainous ridges and other elevated points where the downward pressure of the traction rope is so great as to throw the empty cars out of plumb.

Self-dumping buckets are furnished when required, as shown in Figs. 7 and 8. At any desired point for dumping, a short bar attached to the track cable disengages a latch attached to the hanger, releasing the bucket, which is so hung that it instantly discharges its contents. Special receptacles are also made to suit the material to be carried, some of which are illustrated in the chart of details.

THE SUPPORTS.

The supports may be of wood or iron, as preferred, and the illustrations herein show the ordinary construction or tower support. Other designs, however, are made to correspond with the weight they have to sustain and to meet the special conditions involved.

The spacing of the supports depends altogether on the contour of the ground. On level stretches, the distance is from 200 to 250 feet, according to the

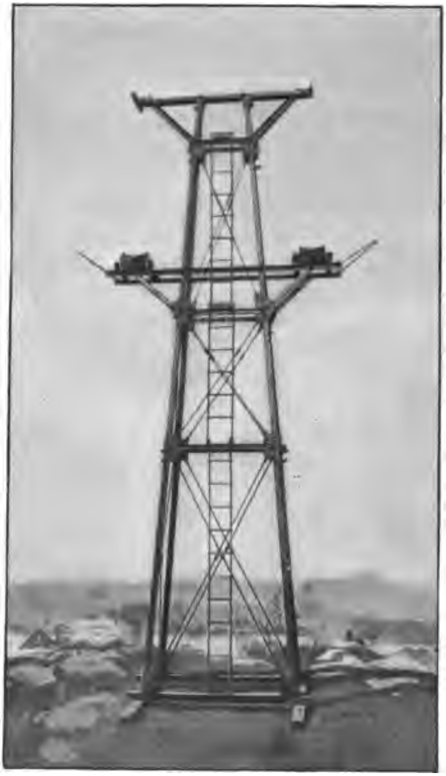
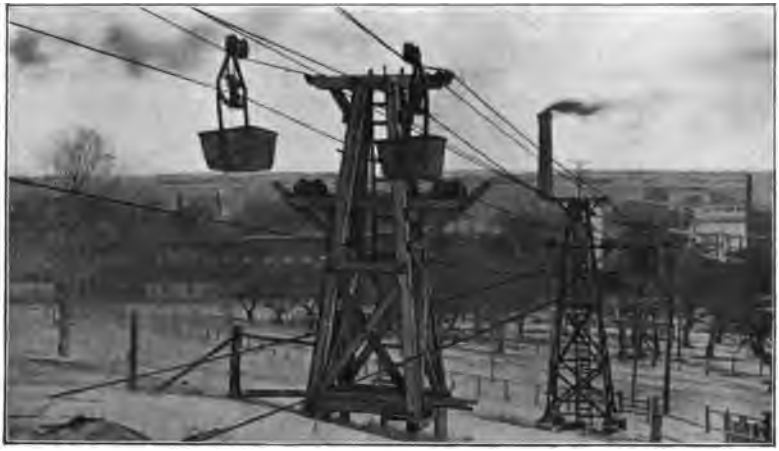


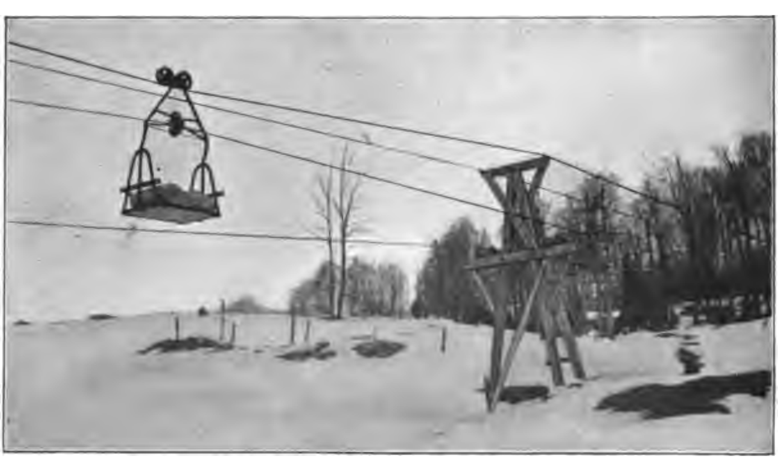
Fig. 10. IRON SUPPORT.



Length of line, 16,500 feet. **BLEICHERT TRAMWAY,** Hourly capacity, 75 tons.

Built by THE TRENTON IRON CO., Trenton, N. J.,

For the Solvay Process Co., Syracuse, N. Y. View showing wood and iron supports.



Length of line, 2,400 feet. **BLEICHERT TRAMWAY,** Hourly capacity, 2½ tons.

Built by THE TRENTON IRON CO., Trenton, N. J.,

For The New England Talc Co., Stockbridge, Vt., showing platform car.

capacity of the line. Where the contour is rugged and irregular (see profile sheets), the distances between the supports will vary greatly, being closer on the ridges and wider apart in the valleys. Where the ridge is a very sharp one, structures known as "rail stations" are erected, which consist of a series of bents, from 15 to 20 feet apart, supporting rails which overlay the track cables, and save the latter from undue wear at these points. In crossing ravines, valleys and rivers, on the other hand, clear spans have been made up to 2,200 feet, one of this length occurring in the line of the Silver Lake Mining Company, Col., experience having demonstrated that long spans where practicable are not objectionable.

If the line is over a mile in length, it is necessary to apply tension to the track cables at intermediate points on account of the saddle friction, and special stations are erected for this purpose. The track cables are parted at these stations, and the ends either rigidly anchored or counterweighted. The cars pass from one section of the cable to the next by means of intervening rails, so that no interruption occurs in the continuity of the track.

ADVANTAGES OF THE BLEICHERT SYSTEM.

1st.—*It is adapted to the heaviest traffic.* Loads up to a ton in weight may be carried and from 800 to 1,000 tons per day transported, which is not possible with any kind of single-rope tramway.

2d.—*A speed of 3 to 4 miles per hour can be maintained,* which is not practicable in single-rope lines of the Hallidie type, not only on account of the trouble due to the dropping of the rope from the shallow supporting sheaves, but mainly on account of the fact that the buckets are permanently attached to the rope so that their loading and discharge must be effected while they are in motion.

3d.—*The number of cars required for a given service is less than on other lines.*

4th.—*The steepest grades can be surmounted without difficulty.*

5th.—*Less power is required, or more developed, as the case may be, than in any other system.* This is due to the fact that the traction rope, instead of being loaded down by the cars, as in single-rope lines, is itself supported by them, to a certain extent, as already explained. In other words, a Bleichert tramway will work by gravity on a lesser grade for a given output than any other. For instance, the line of the Old Dominion Copper Co., which has a fall of only 100 feet in a total length of 1,250 feet, runs by gravity on a daily output of 150 tons.

6th.—*The most important advantage is the low cost of operation and maintenance.* This is due not only to the substantial manner in which these lines are constructed, the less wear and tear, and less power required, but also to the fact that the greater amount of material handled requires no extra labor.

TYPICAL LINES.

Of the many lines that we have built, a brief description of a few, illustrations of which appear in these pages, will be of interest as demonstrating the practical economy and efficiency of the system.

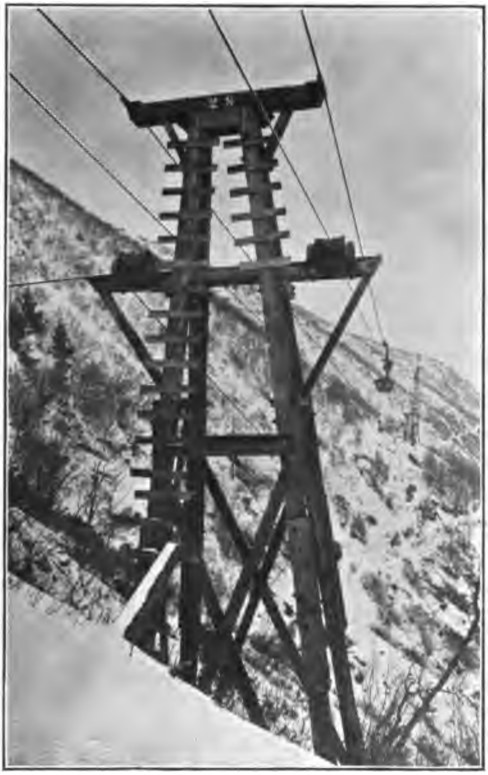
Its adaptability to mountainous sections is well represented in a number of lines, among which that of the Bunker Hill and Sullivan Mining and Concentrating Co., Idaho, is especially interesting, from the fact that it passes over the town of Wardner in a clear span of 1,173 feet, as shown in the frontispiece. The total length of the line is 9,000 feet, and the fall 713 feet, which is amply sufficient for it to run by gravity. At two points where the tramway passes over mountain crests it is supported by rail stations, such as referred to on the preceding page. These are low structures and are therefore roofed in to protect them from snow. The tramway is used to transport silver and lead-bearing ores from the mines to the concentrating works, at Kellogg, and has carried as much as 50 tons per hour, which is somewhat remarkable, in view of the fact that the buckets hold but from 700 to 750 pounds each, making the corresponding intervals between them 25 to 27 seconds. The line was designed to carry only 40 tons per hour. The average output is 15,000 tons of ore per month, which is transported at a cost of less than 5 cents per ton per mile, two-thirds of which represents labor and the balance supplies and repairs.

A line built for the Silver Lake Mining Co., near Silverton, Col., for transporting gold and silver-bearing concentrates, is operated in two sections. The first section, or original line, is 8,400 feet long with a fall of 2,100 feet, and the second section is 6,200 feet long with a fall of 659 feet, terminating at the new mill. The upper section was originally designed for a capacity of five tons per hour, but with the installation of the new mill the capacity has been increased to thirty tons per hour. The latter output is sufficient to develop about 50 horse-power. From the loading terminal, the line ascends a mountain slope for a short distance on an inclination of 1:2½, and rounding the crest of the mountain it pitches down on the opposite side on an inclination of 1:1.8, crossing snow slides in long spans, one of which is nearly half a mile in length, and is the longest span of any similar wire rope tramway in the world. There are but 19 supports in the upper section, making the average spacing outside of the long span referred to over 300 feet. Another line near this, built for the Iowa Gold Mining and Milling Co., contains an equally long span.

Mr. T. A. Rickard, in an article on "Mining at High Altitudes," published in Cassier's Magazine for October, 1902, says: "One of the best installations in Colorado is, I think, that of the *Camp Bird* mine, near Ouray. This *Bleichert Tramway* connects the mine with the mill, the distance being 9,000 feet and the descent 2,109 feet. * * * Each of the buckets, of which there are forty-six, carries 750 pounds of ore. They travel at the rate of 350 to 450 feet per minute. Under these conditions the tramway has a capacity of about 120 tons in ten hours, but both speed and number of buckets can be increased without danger, so that the capacity could be 450 tons per twenty-four hours.

"The cost of transporting the ore, in this case, with an output of 3,100 tons per month, is fifteen cents per ton, but this includes the carriage to the mines of supplies of all kinds which are loaded into the empty returning buckets. This feature of mountain tramways is most important, because during several months the trails are often impassable by reason of snowdrifts."

A notable western line is that erected at the Highland Boy mine, near Bingham, Utah, in the fall of 1898. The length is 12,700 feet. The



Length of line, 12,700 ft. Hourly capacity, 35 tons.

BLEICHERT TRAMWAY,
Built by THE TRENTON IRON CO., Trenton, N. J.,
For the Highland Boy Gold Mining Co.,
Bingham, Utah.

elevation of the loading terminal is 1,120 feet above that of the discharge terminal, and the line therefore operates by gravity. It was originally designed for a capacity of 25 tons per hour, but the development of the mine and increased capacity of the smelter made it necessary to carry 35 tons per hour, which was readily and economically done by simply adding a few more cars and slightly increasing the speed of the traction rope. Over 350,000 tons of ore have been conveyed at a cost of 7¾ cents per ton of 2,000 pounds for labor and repairs, without any apparent deterioration in the condition of track cables and traction rope.

A carrier specially designed for the conveyance of ore in sacks is illustrated in Figs. 11 and 12. This style of carrier was used for several years on a line built for the Consolidated Kansas City Smelting and Refining Co., of El Paso, Tex., to transport ore across the Rio Grande, from the Mexican to the United States side, a distance of 2,500 feet. It has since been removed and re-erected in another location as part equipment of a longer line.

Figs. 13 and 14 illustrate a type of carrier used on a line built for the

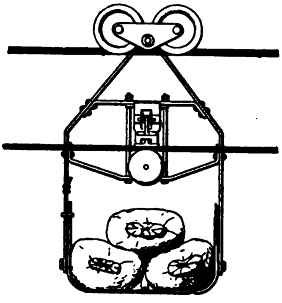


Fig. 11.

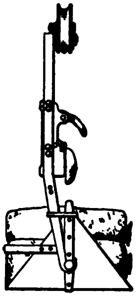


Fig. 12.

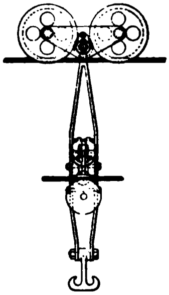


Fig. 13.

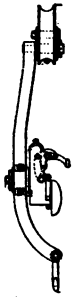
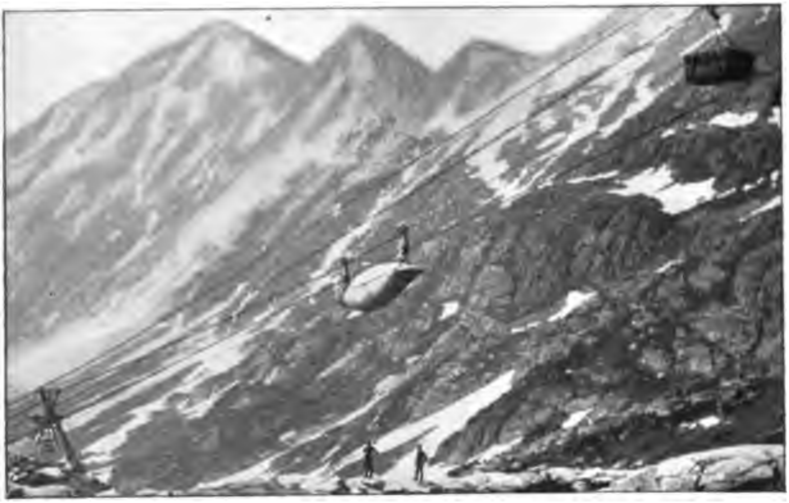


Fig. 14.

Chilkoot Railroad and Transport Co., which was seven miles in length, operated in two sections. This line ran over the famous Chilkoot Pass, and was used for about two years for conveying merchandise and passengers to the Klondike Mines, and ore from the mines to the terminus at Canon Camp, where it connected with the railroad to Dyea. It has since been purchased by the White Pass Railroad Co. and dismantled, communication now being effected entirely by railroad. (See illustration on the following page.)

It is frequently desired to convey material across a river where a bridge would be impracticable or too expensive, and in such instances, which are numerous in the mining regions, the Bleichert system offers a most convenient and economical means of transport. The illustration on page 6 is a view of such a line, operated by the Royal Coal and Coke Co., at Prince, West Va., for the conveyance of coal from their mine on the south side of New river to the Chesapeake and Ohio railroad on the opposite side. It served the purpose very satisfactorily for about ten years, when a railroad having been built on the south side, there was no occasion for its further use, and the coal is now conveyed to the new road by a gravity plane. The wire rope tramway was 2,800 feet long with a fall of 820 feet, and developed about 50 horse-power in carrying an output of 80 tons per hour. The span across the river was 665 feet.

A similar line, illustrated on the following page, is operated by the Keystone Coal Mining Co., at East Brady, Pa., for transporting coal from

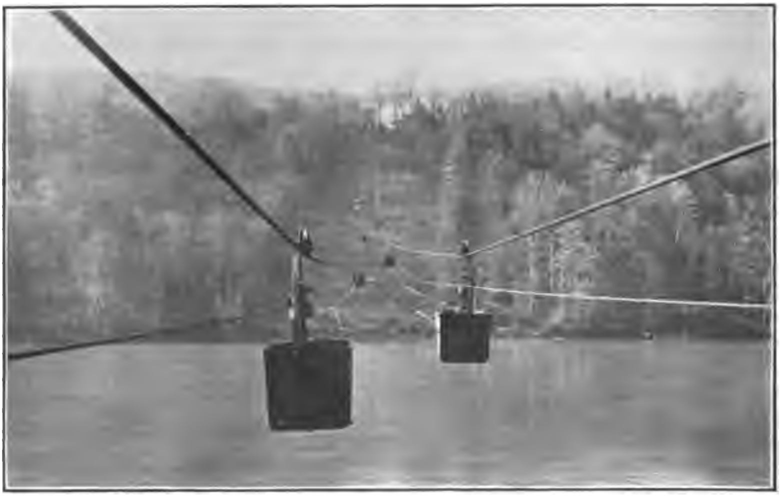


Length of line, 7 miles. BLEICHERT TRAMWAY, Hourly capacity, 5 tons.

Built by THE TRENTON IRON CO., Trenton, N. J.,

For the Chilkoot Railroad and Transport Co.

View at the Chilkoot Pass.



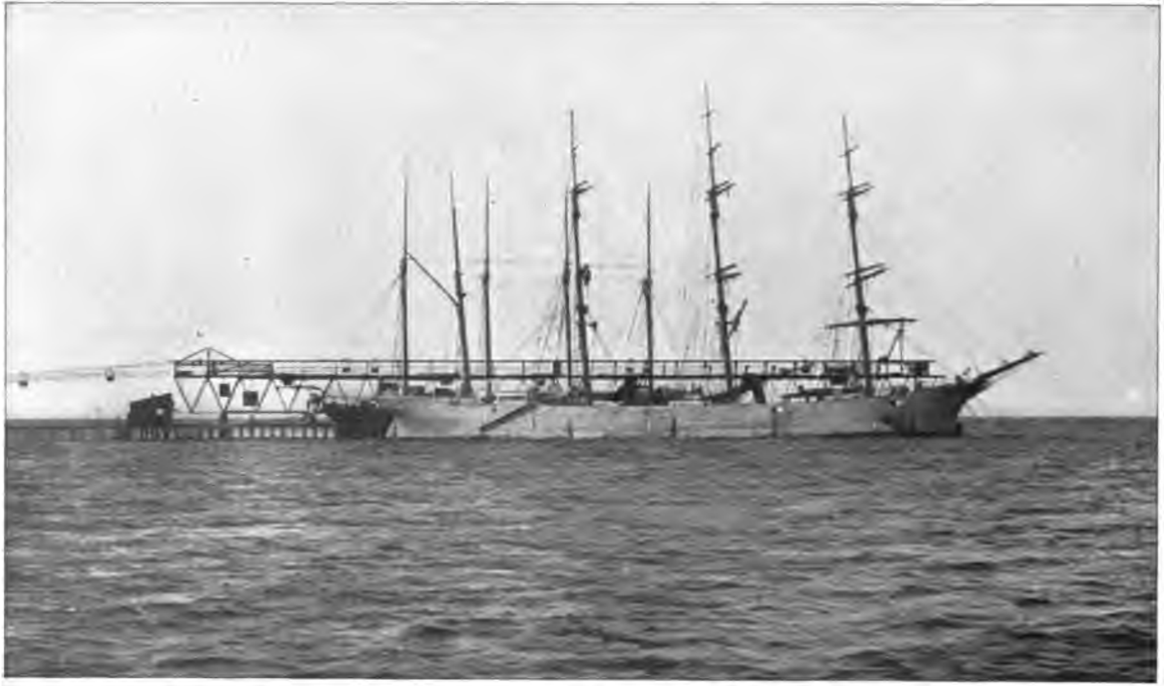
Length of line, 1,400 feet. BLEICHERT TRAMWAY, Hourly capacity, 80 tons.

Built by THE TRENTON IRON CO., Trenton, N. J.,

For the Keystone Coal Mining Co., East Brady, Pa.

the mine on one side of the Allegheny river to the railroad on the opposite side. This line is 1,400 feet in length with a fall of 200 feet, and develops about 5 horse-power on an output of 40 tons per hour, the line being designed to carry eventually 80 tons per hour. The span across the river is 1,009 feet.

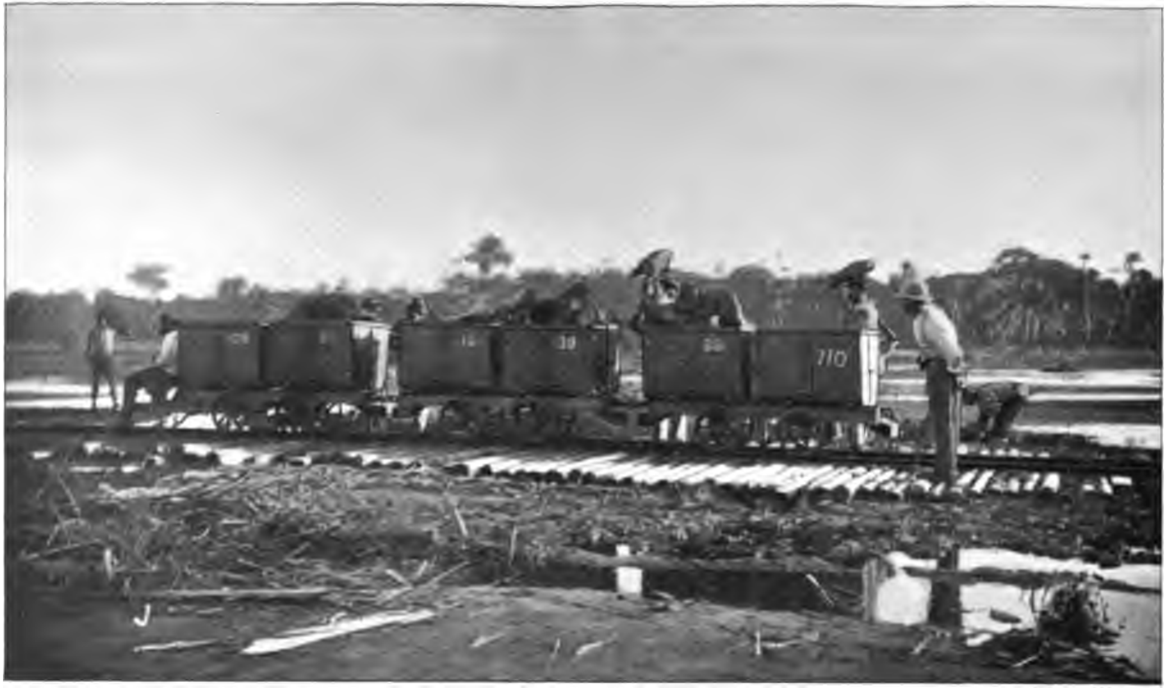
The line of the Trinidad Asphalt Co., on the Island of Trinidad, for conveying asphalt, is an instance of the adaptability of the system to comparatively level ground, where the conditions preclude the use of surface tracks, and also its adaptability to the loading of vessels at sea. The length is 5,100 feet and the entire structure is of iron, including the framework of the terminal stations as well as the intermediate supports. The loading terminal is located at a point upon the edge of the lake, and the discharge terminal is an iron pier, 350 feet long, built out in deep water, 1,750 feet from the shore. A view of this end of the line is shown on the following page. The fall from lake to pier is but 80 feet, most of which occurs in the last 500 feet. Seventy-five tons per hour is the capacity of the line, requiring about 20 horse-power. At the loading terminal, the line connects with a surface tramway, running in a circuit over the lake, the consistency of the material being such as to render this practicable. While the material is quite soft in the center of the lake, it is hard enough for a considerable distance from the border to support heavy weights; so hard, in fact, that the original design contemplated an extension of the Bleichert tramway over this lake, with loading terminal near the center and lateral branches to the diggings. It was discovered, however, that the whole mass was in slow motion, the movement being discernable only after the lapse of long intervals by the relative changes in the positions of the small islands and other objects. This led to the adoption of a surface tramway for the lake haul, the termination of the wire rope tramway at the border of the lake, and the transferring of the buckets from one line to the other. The surface cars each hold two buckets, and are propelled by an endless rope running continuously in one direction, to which they are attached by means of grips. The same engine that operates the wire rope tramway also drives the surface tramway. In order to avoid the slow submergence of the track, which would occur if it had been laid directly on the asphalt surface, the



Length of line, 5,100 feet. BLEICHERT TRAMWAY, Hourly capacity, 75 tons.

Built by THE TRENTON IRON CO., Trenton, N. J.,

For the Trinidad Asphalt Co., La Brea, Trinidad,
showing discharge terminal on iron pier.



ENDLESS ROPE HAULAGE,

Built by THE TRENTON IRON CO., Trenton, N. J.,

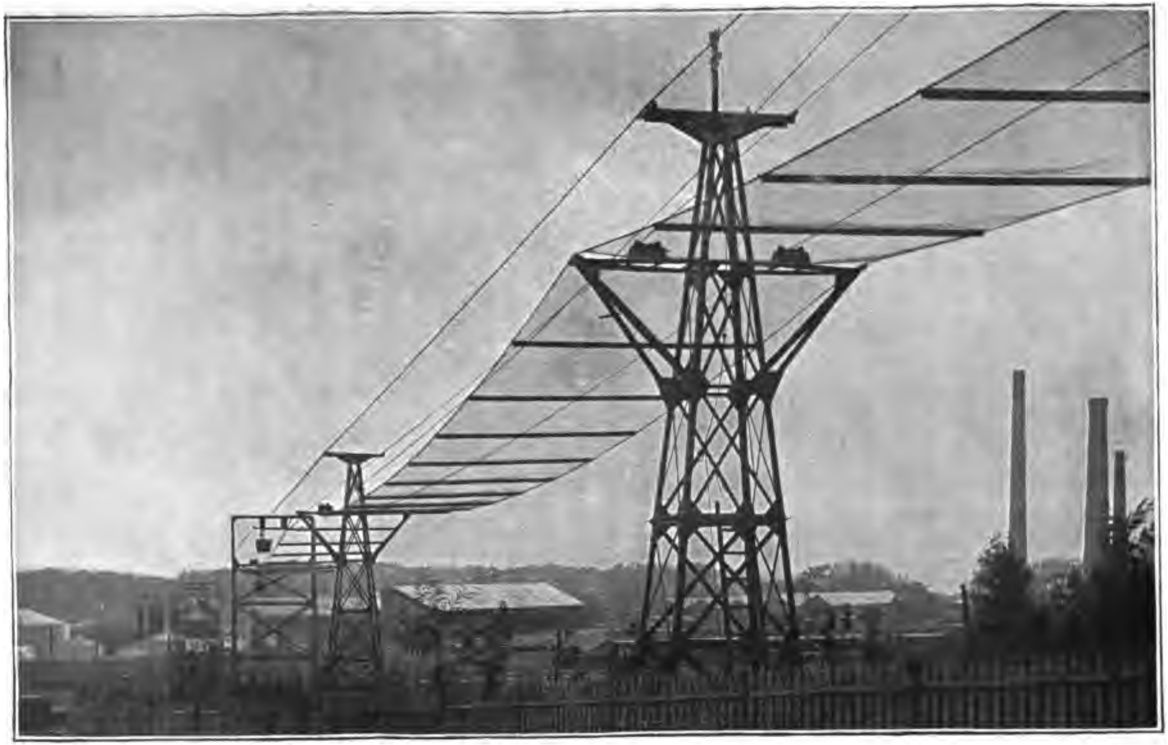
For the Trinidad Asphalt Co., La Brea, Trinidad. View of Pitch Lake.

rails are laid on a corduroy of palm, resting on a mattress of cocorite palm leaves, as shown in the view on the preceding page. At certain points in the circuit, guy lines extend to anchorages on the shore in order to keep the track in place.

The line of the Solvay Process Co., near Syracuse, N. Y., used for the transportation of lime rock, is 3⅛ miles long, and has an hourly capacity of 75 tons. It passes over ordinary rolling ground, much of which is farm land, and the contour presents no unusual conditions. This line has been running day and night for twelve years, and the cost of operating, as determined from actual records, is about 6 cents a ton per mile, which includes, in addition to labor and repairs, the expenses of right of way and taxes. The line has proved so satisfactory that the company have built an extension and branch lines, the total length of which is nearly equal that of the original line. The elevated station at the works has been entirely re-modeled and built of iron and now constitutes not only the terminal of the main line that brings the rock from the quarries, but also the terminal of a couple of branch lines for handling coke, ashes, and refuse material, etc., making it a central point from which all the materials are brought in and sent out to their various destinations. In collecting and distributing the materials about the works, transfer cars, such as shown on the preceding page, are extensively used, and the tramway cars are raised and lowered at the central station by elevators specially designed for the purpose.

The Compagnie Haitienne, of New York, are operating a Bleichert tramway on the island of Hayti for the transportation of logwood, the total length of which is 12 miles. The tramway is divided into three sections, each of which constitutes a distinct line in itself, with independent power, the driving stations being located at points where bends occur. The cars at these stations are transferred in the usual way from one section to the next by means of shunt rails, so that no re-handling of material occurs. At the driving stations, sufficient power is provided not only to run the tramway, but also to operate pumps for purpose of irrigation. The entire structure is of iron.

A line at the United States Military Academy, West Point, N. Y., 1,640 feet in length and 37½ tons hourly capacity, replaced a system of



Length of line, 11,550 feet.

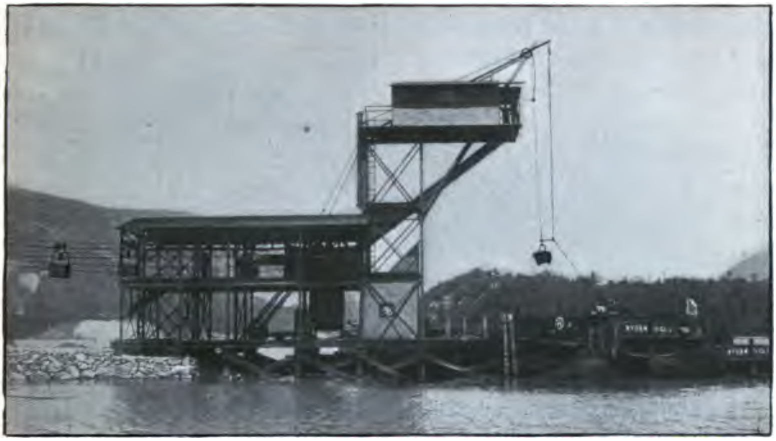
BLEICHERT TRAMWAY,

Of Lubimoff, Solvay & Co., Russia; showing guard-net.

Hourly capacity, 55 tons.

industrial railways in previous operation. The line is used for conveying coal from vessels, to bins at two storage houses, passing over one where the gas coal is stored, to the main bins at the upper terminal station. There is one support between the dock and the gas-coal bins. The coal is elevated at the dock 40 feet by an independent hoist (see illustration on the opposite page), the buckets holding each 750 pounds. When a loaded bucket reaches the desired height, it is dumped upon a chute terminating at a hopper at the lower end, from which the tramway buckets are filled. The gas coal is discharged while the cars are in motion, without detaching from the traction rope. The other coal passes to the upper terminal station, and is there dumped into special cars travelling in an endless circuit upon tracks above the bins, the cars holding each one ton of coal, and discharging from the rear ends, which are fitted with chutes that are opened by the operator at any desired point. These cars are moved by a ½-inch wire rope running continuously along the inside rail of the track at a speed of 132 feet per minute, which is driven by a grip-wheel 42 inches in diameter on the main shaft. The structural work is entirely of iron, excepting the station over the gas-coal bins, and the entire plant is operated by electric power, one motor running the tramway and distributing line at the upper terminal station, and an independent motor being used to operate the hoist at the dock.

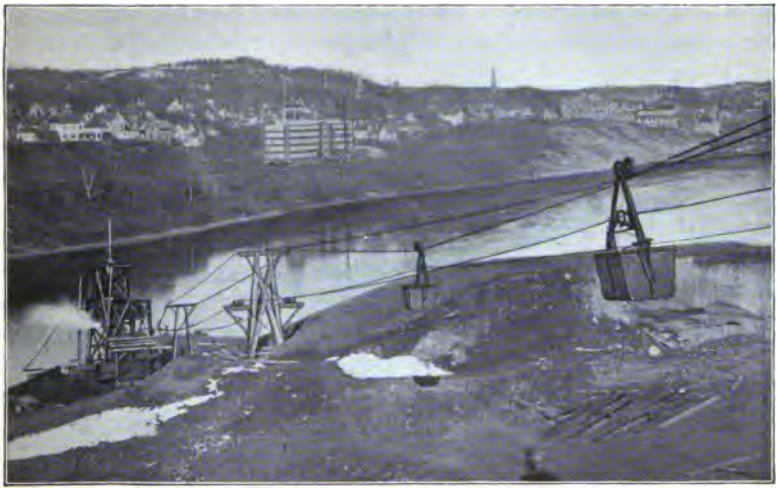
A similar line, of 30 tons hourly capacity, was built for the Maine Insane Hospital, at Augusta, Me. The structural work in this case was of timber, and the dock hoist, a view of which is shown on the opposite page, has an inclined iron beam that projects out over the vessel and on the lower flanges of which the hoist-carriage runs, the beam being arranged so that it can be pulled back clear of the rigging of vessels when landing or departing. The bucket attached to a fall-block below the carriage is raised and lowered by means of a ½-inch wire rope operated by an independent engine. The carriage with the empty bucket runs out first to the lower end of the beam and then drops vertically into the hold of the vessel. After loading, it is hoisted until the fall-block comes up against the carriage, when the operator continuing to wind in the rope, the carriage with the loaded bucket is drawn up along the beam and back over the



Length of line, 1,640 feet. BLEICHERT TRAMWAY, Hourly capacity, 37½ tons.

Built by THE TRENTON IRON CO., Trenton, N. J.,

At the United States Military Academy, West Point, N. Y.
View of loading terminal and dock hoist.



Length of line, 1,050 feet. BLEICHERT TRAMWAY, Hourly capacity, 30 tons.

Built by THE TRENTON IRON CO., Trenton, N. J.,

At the Maine Insane Hospital, Augusta, Me. View showing
loading terminal and dock hoist.

hopper into which the bucket discharges automatically, and from which the tramway buckets are loaded.

The report of the hospital board for 1899 states that "the new tramway was constructed late in November, but in season to use for transporting coal from the vessel to the coal pocket, at a distance of 1,050 feet and an elevation of 150. The stevedores were formerly paid 29 cents for discharging the coal from the vessel and wheeling it on the wharf. We have been able by the use of the tramway to discharge the coal from the vessel directly into the pocket, at an expense not exceeding 25 cents per ton, thus doing away with the cost of shoveling it into carts and hauling it up the hill; the result has been a net saving of about 70 cents per ton."

A line built for the Cambria Steel Co., Johnstown, Pa., is interesting from the fact that it crosses the main tracks of the Pennsylvania Railroad. As a precaution against accidents, an iron bridge, 220-foot span, was built over the tracks, as shown in the view on the opposite page, the bottom and about three feet of each side being encased by sheet iron. Since an accident in crossing the Pennsylvania Railroad might result in loss of life, the structure is a much more elaborate and substantial affair than ordinarily constructed for such purposes. In most cases, a wire netting, supported by wire ropes attached to the supports, is sufficient, such as illustrated on page 25.

The line of the Plymouth Cordage Co., referred to on page 12, which is used for carrying baled hemp from a warehouse to their cordage factory, is interesting from the fact that it makes a right-angled bend at the end of the warehouse around which the cars pass without detaching from the traction rope (see illustration on the opposite page). Along the warehouse for a distance of 500 feet shunt rails extend so that cars can be loaded at numerous points, special apparatus being provided for releasing the traction rope while the cars are being loaded. Immediately after passing the angle station the loaded cars ascend an incline of about 40 per cent. and thence pass over a guard-bridge spanning the railroad to the factory on the opposite side. The satisfactory operation of this line now for several years has fully demonstrated the practicability of passing bends automatically, and marks an advance in the adaptabilities of this method of transportation.

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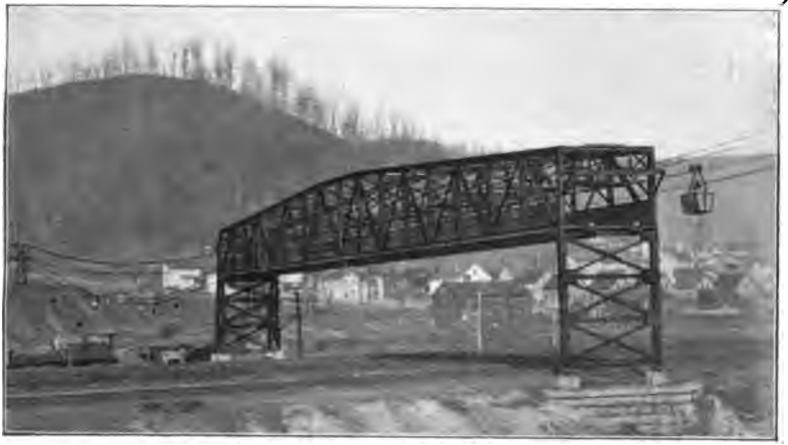
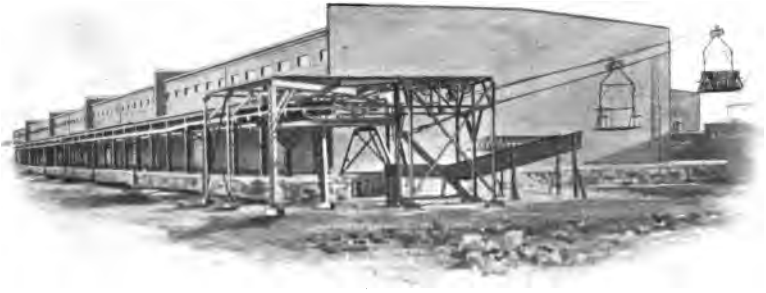


Length of line, 3,260 feet. BLEICHERT TRAMWAY, **Hourly capacity, 50 tons.**

Built by THE TRENTON IRON CO., Trenton, N. J.,

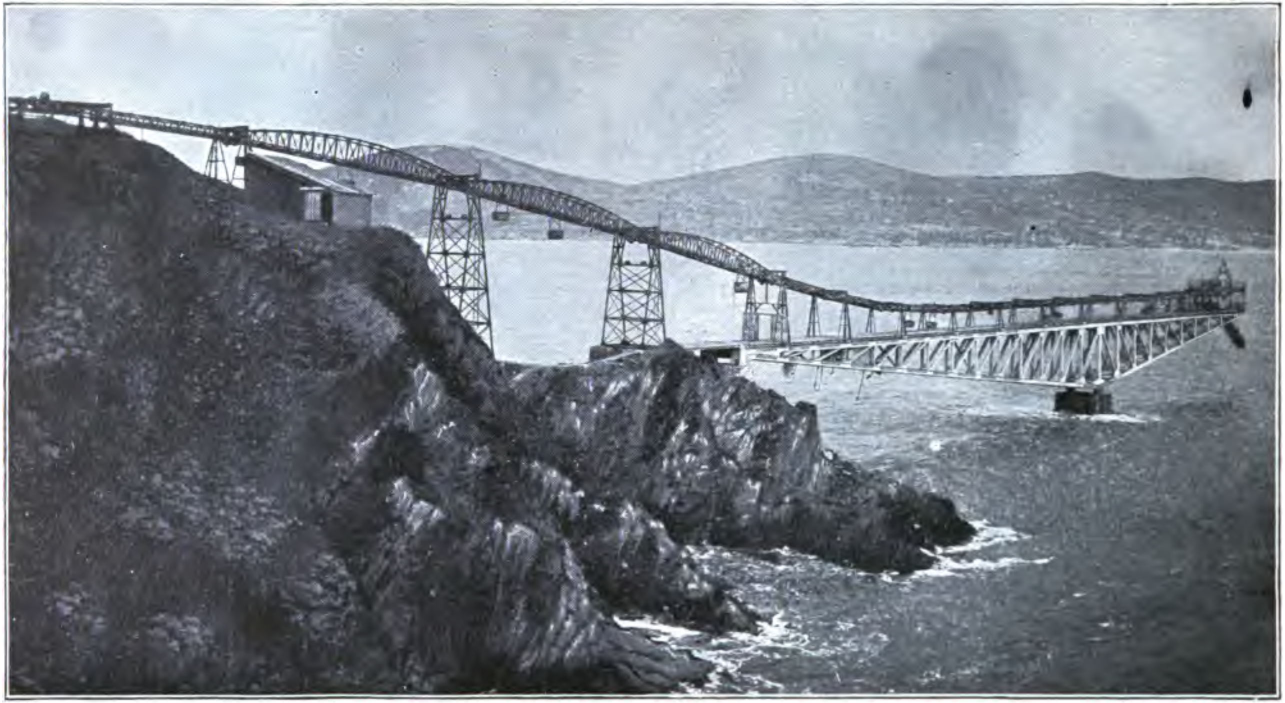
For The Cambria Steel Co., Johnstown, Pa. View of guard-bridge across the Pennsylvania R. R.



Length of line, 1,150 feet. WIRE ROPE TRAMWAY, **Hourly capacity, 7½ tons.**

Built by THE TRENTON IRON CO., Trenton, N. J.,

For the Plymouth Cordage Co., Plymouth, Mass. View of angle station.



Length of line, 625 feet.

BLEICHERT TRAMWAY,

Of The Vivero Iron Ore Co., Spain.

Hourly capacity, 250 tons.

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Testimonials.

From THE EAST RIDGE COAL COMPANY.

MINERSVILLE, Pa., October 29, 1902.

Mr. Charles E. Hewitt, General Manager, The Trenton Iron Co., Trenton, N. J.:

DEAR SIR—Referring to the Bleichert Tramway you built for us in 1901, which we use for carrying culm from the culm-bank to the washery, a distance of about 1,300 feet, with an elevation between the loading and discharge terminals of 190 feet, the discharge terminal being above the loading terminal, would say that during March, April and May, we carried on an average 700 tons per day, at a cost of $2\frac{7}{10}$ cents per ton for transportation and labor of handling at both terminals, which includes gripmen, dumpers, loaders, engineer and runners.

We started our tramway on October 23d, after five months' idleness caused by the strike; we carried 200 tons the first day, this output being small because the chutes in the breaker were rusty from being idle so long.

Our expenses for repairs on the tramway have been $36.00 since last January, which is about $\frac{1}{5}$ of a cent per ton.

It is run by a single engine of 100 H. P., which not only drives the tramway, but drives twelve shakers besides; therefore a 50 H. P. engine would run the tramway, which I consider is a remarkable saving over either cars and plane or conveyor lines.

In view of the foregoing facts, I can heartily recommend it for transporting culm either to or from the breakers. Yours respectfully, B. E. KINGSLEY, *General Manager.*

TRANSLATION.

MONTERREY, Mexico, Sept. 25, 1902.

Messrs. Van Voorhis & Sanford, Agents for The Trenton Iron Co., Monterey, N. L.:

DEAR SIRS—In reply to your favor of recent date relating to the Aerial wire rope Tramway, "Bleichert" system, which you sold us for the "Voladora" and adjoining mines, we take pleasure in communicating to you that ever since the completion of the line it has been in active service, working at a rate greatly in excess of the guaranteed capacity.

We are at present transporting over this line 6,000 metric tons of ore monthly, a distance of 14,000 feet, with a difference of elevation between terminals of 3,200 feet, at a cost not exceeding eighteen cents (Mexican currency) per ton.

We are very pleased to render you this information, for you to use in any way you may see fit, and to say that we are entirely satisfied with the tramway.

(Signed,) CIA. METALURGICA DE TORREON,
DONALD R. MORGAN, *Sup't.*

SALT LAKE CITY, Utah, Feb. 5, 1901.

Trenton Iron Co., Trenton, N. J.:

GENTLEMEN—Please ship to the Centennial-Eureka Mining Co., Eureka, Utah, a set —fourteen (14)—of new buckets for their tramway, furnished in December, 1899.

* * * * * * * * *

You will be interested to know that the tramway continues to work perfectly satisfactorily; the superintendent said yesterday that the ropes show no signs of wear yet; line has been working a year and every day at more than its rated capacity.

They have put a large engine lubricator over the loaded rope, which feeds oil slowly on to a bunch of wicking, each outgoing car wipes off the oil on its wheels and so transfers it to the standing ropes, which seems to have conduced largely to their slight wear.

Yours respectfully, (Signed,) JONES & JACOBS.

From THE BUNKER HILL AND SULLIVAN MINING AND CONCENTRATING CO.

KELLOGG, Idaho, March 15, 1896.

The Trenton Iron Co., Trenton, N. J.:

GENTLEMEN—In reply to your favor of the 5th inst., regarding the operation of our Bleichert tramway, I am pleased to say that the line is working to our entire satisfaction.

The tramway to date has transported from our mine to our mill 450,000 tons of ore. On the larger portion of the line the original carrying cables are still in use, and are apparently good for considerable additional tonnage. The present traction rope has been in use in transporting 180,000 tons of ore, and apparently is still in good condition. During the last six months (September, 1895, to February, 1896, inclusive) the tramway has transported from mine to mill 236,806 buckets of ore in a total working time of 2,208 hours, of which 172 hours were lost, as follows:

28 hours changing lugs.

93 hours because of repairs (includes coupling in three new pieces of carrying cable at different times).

27 hours on account of accidents.

24 hours on account of telephone line and electric lights being out of order, and ore frozen in chutes, and other like causes.

In this period the tramway averaged $107\frac{25}{100}$ buckets of ore per hour of total time, or $116\frac{31}{100}$ buckets of ore per hour of actual time in operation. For the above period the average weight of ore carried by a bucket was 732 pounds. There are 127 buckets

(5 cubic feet capacity) on the line placed 140 feet apart. The tramway carries from the mill to the mine 10 to 12 cords of wood per day, and could carry more if we required it. The operation of the line develops some power which is used for hoisting purposes.

The total operating and repair crew is as follows:

1 foreman.
2 tramwaymen at mill.
1 brakeman at mine.
1 bucketman at mine.
4 tramwaymen at mine.

I hope the foregoing, together with the data you already have, will give you all the information you wish regarding our tramway. Yours truly, F. W. BRADLEY.

KELLOGG, Idaho, May 20, 1901.

H. N. Elmer, Esq., Trenton Iron Co., Chicago, Ills.:

DEAR SIR—I am sorry I did not see you in Spokane the other evening. When I received your letter you had already left the city. I am at a loss to know why anybody should be talking about the excessive cost of tramming Bunker Hill ore. As a matter of fact, it is about as cheap transportation as it is possible to obtain. Our average cost per ton of ore trammed, including repairs and maintenance, amounts in round numbers to ten cents. We have for the last year or more been running the tramway two shifts of ten hours and nine hours respectively, and have, within the last month, increased the time of operation to two twelve-hour shifts, with a view of handling a larger tonnage of ore. We have a total force of 17 men on the two shifts, which includes the foreman, brakeman, lineman, loaders, dumpers and repairmen. The total cost of labor is $62.50 per day, and we are tramming from 850 to 900 tons per day, making the labor cost of, say, 7 cents per ton. (3½ cents per ton per mile.)

Referring to your sketch of terminal rail; the total length of the loop is about 90 feet, and only two men are engaged on each shift at the lower terminal. One of these dumps the buckets, and the other grips the outgoing bucket. They change off with one another every hour. If any other information is desired, I shall be glad to send it.

Yours truly, (Signed,) FREDERICK BURBIDGE.

SILVERTON, Colo., Aug. 1st, 1900.

Trenton Iron Co., Trenton, N. J.:

GENTLEMEN—Yours of the 20th inst. at hand and contents noted.

In regard to the automatic scale, I possibly misunderstood Mr. Elmer, and as we are dropping buckets in so fast with our new tramway that it would be impossible to weigh them except automatically, you can cancel that part of the order.

I am very much pleased to say that our new line is running perfectly.

Very truly yours, GOLD KING CONSOLIDATED MINES CO.,
By W. Z. KINNEY, *Sup't.*

TELLURIDE, Col., December 14, 1896.

Trenton Iron Co.:

GENTLEMEN—Your 1896 edition of wire rope transportation, etc., has been duly received, for which accept thanks.

Yours truly, TOMBOY GOLD MINES CO.,
Per A. H. BROWN.

P. S.—Our new tramway is giving splendid satisfaction.

From THE VERMONT MARBLE CO.

PROCTOR, Vt., April 2, 1896.

The Trenton Iron Co., Trenton, N. J.:

GENTLEMEN—We have used constantly the wire rope tramway which you installed here in June, 1894, and found it in every way very satisfactory. It conveys sand from a bank to our mill, a distance of about a quarter of a mile, carrying 100 to 150 tons per day. It runs easily, smoothly, without breakdowns, and the expense of repairing is very trifling. It has been a great saving to us, and we take great pleasure in speaking of it in the highest terms. It is in every way what you recommended it to be.

Yours very truly, FLETCHER D. PROCTOR, *President.*

NOTE.—This line has been extended to a length of 11,000 feet and adapted to a capacity of double that of the old line.

From THE TRINIDAD ASPHALT CO.

NEW YORK, March 9, 1896.

The Trenton Iron Co.:

GENTLEMEN—Replying to your inquiry of the 5th inst., we have to state that the plant for the loading of crude asphalt from the pitch lake, in Trinidad, has been in operation for the past eighteen (18) months and has given very satisfactory results. The asphalt is loaded in buckets at the pitch lake, and, by means of the Bleichert tramway erected by you, is transported to and deposited in the holds of vessels lying alongside the pier with only one handling. We are now transporting from 550 to 650 tons per day when running, and are putting the material on board vessel at a much less cost than under the old system, when the loading was done by means of carts and lighters. We have no hesitation in expressing our pleasure at the very satisfactory results which have been obtained.

Very truly yours, A. L. BARBER, *President.*

From THE OLD DOMINION COPPER CO.

GLOBE, Arizona, April 24, 1892.

The Trenton Iron Company, Trenton, N. J.:

GENTLEMEN—I have your favor of the 13th inst. and note contents of same carefully.

The Bleichert tramway procured from you last year was erected by us last fall, and put in operation on the 6th of January, 1892. Since that time it has been running daily.

The line is 1,224 feet long, and is used to convey copper ore and limestone from the rock-house at our mines to the smelting plant, the grade being sufficient to run the line automatically but not to develop any additional power. Over this tramway we are now conveying daily 110 tons of copper ore and 30 to 40 tons of limestone in nine hours' working time, at a cost of 8.9 cents per ton. We could easily increase the capacity greatly, as we have frequently run at the rate of 25 tons an hour, which would, of course, bring the cost down proportionately.

We had no trouble in the erection of the line, and have none in working it. Everything about it works so smoothly that no extra attention is needed and no trouble caused, as we are sure of the ore supply in any kind of weather. I am more than pleased with the working of this tramway, and can earnestly recommend it to those requiring a cheap and reliable method of transporting ore from one point to another.

Yours truly,

A. L. WALKER, *Superintendent.*

MONTREAL, Canada, November 27, 1889.

Messrs. Trenton Iron Company, Trenton, N. J.:

GENTLEMEN—With your tramway we are now handling fifty tons of pulp every ten hours. The tramway runs at the rate of two hundred and fifty feet per minute, only, and our experience so far shows that we could easily handle several times more pulp than this at same speed, without the slightest difficulty.

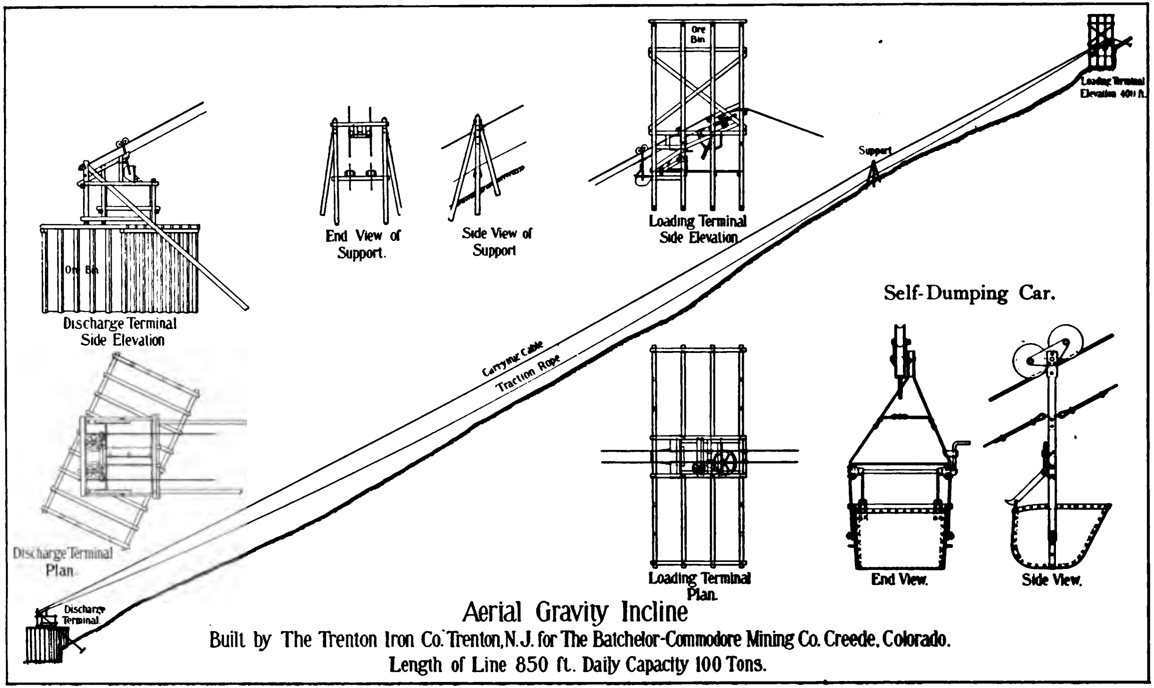
We feel sure, also, that the latter result would not be anywhere near the maximum capacity of the line, but we only speak from actual experience.

When we consider that this tramway takes our product from our wet presses in the mill, carries it across the three channels and intervening islands of the river St. Maurice, the third largest river in Canada, and delivers it 1,500 feet away, on the level of our railway siding, and that we do this with 3 to 5 horse-power, and the labor of only one additional man, at the very most, we are more than satisfied. If there is any other information you require, we shall be glad to give it. Meantime, we remain,

Yours respectfully,

THE LAURENTIDE PULP CO. (LIMITED),

JOHN FORMAN, *Secretary.*



Aerial Gravity Incline

Built by The Trenton Iron Co. Trenton, N.J. for The Batchelor-Commodore Mining Co. Creede, Colorado.

Length of Line 850 ft. Daily Capacity 100 Tons.

Reversible Wire Rope Tramways.

DOUBLE TRACK.

REVERSIBLE WIRE ROPE TRAMWAYS are so called from the fact that the traction rope is given a reciprocating motion, in contradistinction to the Bleichert and single-rope systems in which it is run continuously in one direction. Usually there are two carriers, which are so arranged that as one arrives at either terminal the other arrives simultaneously at the other terminal. This style of conveyor, of course, is limited to comparatively short lines of communication, such for instance, as the transferring of material across a river or ravine, or from one building to another.

The track cables may be either of the patent locked-coil or smooth-coil constructions as described on pages 8 and 9, and the traction rope, which works in an endless circuit about sheaves at each terminal, may be run at speeds from 400 to 800 feet per minute, according to the contour of the ground and the intervening supports.

If power is required, which may be applied at either end of the line, a reversing engine or electric motor may be used to drive, but if the loads travel on a descending inclination, with sufficient fall to run by gravity, the line is operated under control of brakes.

A gravity-acting reversible wire rope tramway, built for the Bachelor-Commodore Mining Co., Creede, Col., is illustrated on the opposite page.

The total length of the line is 850 feet, and difference in elevation of terminal points about 400 feet. The two carriages each travel on 1-inch steel cables, and are attached to a ½-inch traction rope, the movement of which is controlled by brakes at the upper terminal station. Loads of 12 cwt. are carried, and the ore delivered to bins by self-dumping buckets, and thence to a longer wire rope tramway of the Bleichert system, which transports it to the Denver & Rio Grande railway. One hundred tons of ore per day are transported thus, at a very low cost.

A similar line, built for the Compania Metalurgica de Torreon, Coahüila, Mexico, is 1,453 feet long with a fall of 730 feet.

Reversible Wire Rope Tramways.

SINGLE TRACK.

ON THE following pages are illustrations of a cheap and economical reversible wire rope tramway with single-track cable, built for the St. Bernard Coal Co., of Earlington, Ky., for carrying refuse from their coal washer, and is specially designed for dumping at different points along the line.

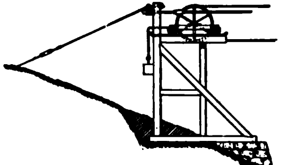
A single bucket holding half a ton, suspended from a carriage running on the track cable (1½ in. diam. smooth-coil), is moved by a 7/16-inch endless wire rope driven by a small reversing engine. Bars clamped to the track cable at the desired dumping points trip a latch on the bucket hanger, releasing the bucket which is so balanced as to discharge automatically. The construction of the latch is such that the loaded bucket passes the bars going out without lifting the latch, but trips in coming back. This arrangement permits the discharge of the bucket at the various dumping points without having to shift any of the bars. One man operates the line.

The bucket is permanently attached to the traction rope, and after dumping, the empty bucket is returned to the loading terminal upside down. If desired, however, a self-righting bucket can be used, and the hanger supporting this can be fitted with a grip, so that it can be detached at either terminal, and, by means of shunt rails, taken to points of loading or discharge as may be, not directly accessible by the cable line.

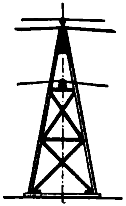
Where power can be taken from some convenient shaft, the traction rope may be operated from either end of the line by double friction clutch pulleys driven by straight and crossed belts, and the material transported in either direction.

Reversible Wire Rope Tramway with self-dumping Bucket

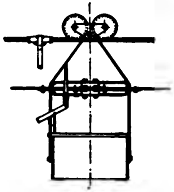
Manufactured by The Trenton Iron Co. Trenton, N.J.



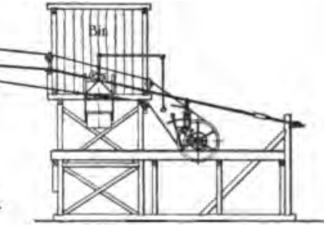
Tension Terminal



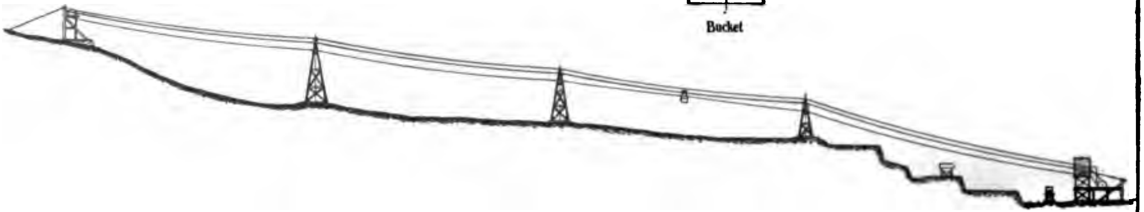
Support

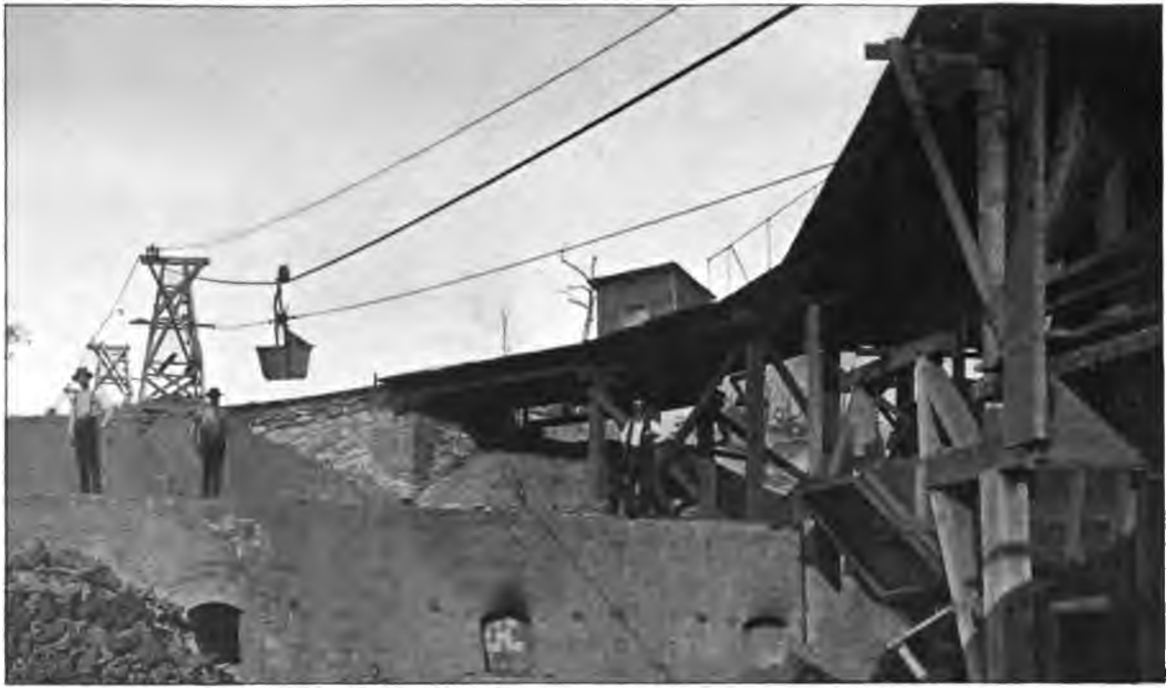


Bucket



Power Terminal





Length of line, 600 feet.

REVERSIBLE WIRE ROPE TRAMWAY,
with Self-dumping Bucket.
Built by THE TRENTON IRON CO., Trenton, N. J.,
For the St. Bernard Coal Co., Earlington, Ky.

Hourly capacity, 10 tons.

The capacity is dependent of the length; the line at Earlington, which is about 600 feet long, having a capacity of 10 tons per hour.

The ground immediately under the line, at Earlington, having been filled in, the bucket is discharged into side-dump cars, by means of which the material is conveyed to the dump banks on either side of the cable line, and a large area thus covered.

Edward Cooper, President, } New York.
Erskine Hewitt, Vice-President, }

Chas. E. Hewitt, Treas. & Gen. Mgr., } *Trenton.*
E. Hanson, Secretary, }

The Trenton Iron Co.

TRENTON, N. J.

MANUFACTURERS OF

WIRE AND WIRE ROPE,

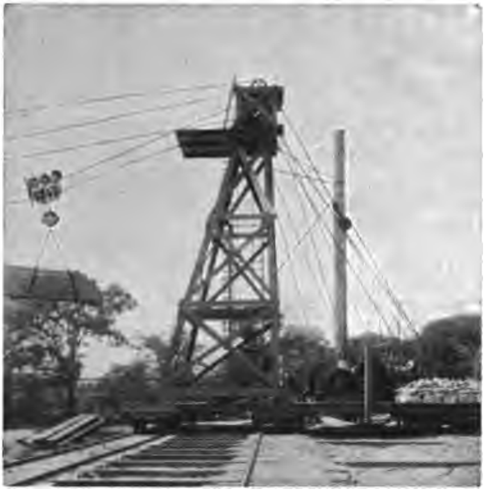
Wire Rope Tramways,

Cable Hoist-Conveyors,

Surface and Underground Haulage and Transmission of Power Equipments.

Suspension Bridges, Etc.

CABLE HOIST-CONVEYORS



Cable Hoist-Conveyor at St. Paul, Minn.

Laurent-Cherry
Patent System,
requiring no
Fall-Rope Carriers,
and
Hall
Patent System,
Specially adapted
to excavating.

MANUFACTURED BY

The Trenton Iron Co.

TRENTON, N. J.

Engineers and Contractors and Sole Licensees in North America for the Bleichert System.
Also, Wire Rope Equipments for Surface and Underground Haulage, Etc.

New York Office—Cooper, Hewitt & Co., 17 Burling Slip.
Chicago Office—1114 Monadnock Building.

Illustrated book, describing the above, will be mailed upon application.

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CABLE
HOIST-CONVEYORS.

Laurent-Cherry Patent System.

No fall-rope carriers required.

The Hall
Patent Cable Hoist-Conveyor,

with self-filling bucket, for excavating, etc.

Hoist-Conveyors
for Loading and Unloading Vessels,

Cable Chutes, &c.

BY WILLIAM HEWITT, M.E.

THE TRENTON IRON COMPANY,
MANUFACTURERS,
Trenton, New Jersey, U. S. A.

1901.

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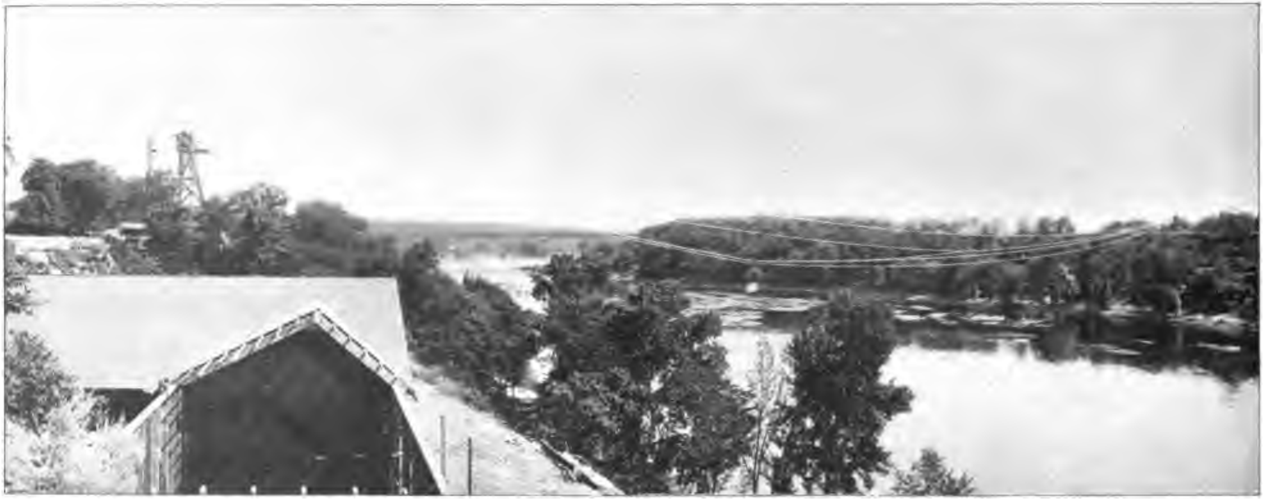
THE BRANDT PRESS, TRENTON, N. J.

Trenton Iron Co.



Span, 1,150 feet. CABLE HOIST-CONVEYOR (Laurent-Cherry System), Load, 5 tons.

Built by THE TRENTON IRON COMPANY, Trenton, N. J.,

For the U. S. Government, at St. Paul, Minn.

Cable Hoist-Conveyors.

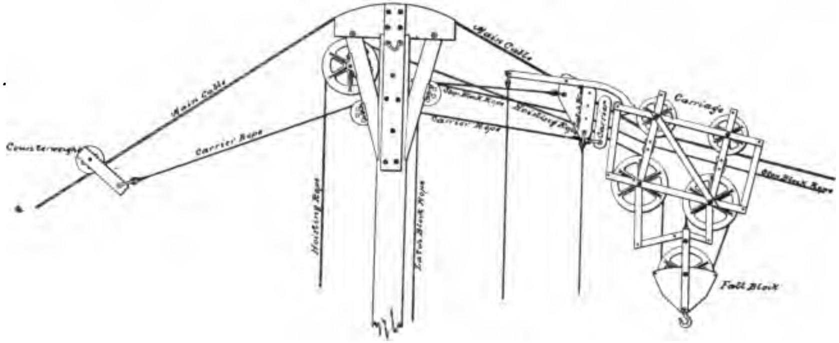
THE CLASS of plants herein described, is to be distinguished from wire rope tramways, in the fact that they are designed to move at any one time single loads of several tons weight over comparatively short distances. Usually but one track cable is employed, in which case the line consists of a single clear span between two towers, the height of which depends on the length of the span, and the deflection corresponding to the safe stress due to the maximum load to be handled, as determined from the formulæ on the last page. In cases where the line is of considerable length and it is impracticable to build towers of the requisite height for a single span, intermediate supports may be introduced, but in this case a double line of track cables must be employed on account of the construction of the ordinary carriage, which straddles the single cable, and hence would not pass such supports. By using two cables a construction of carriage is obtained in which the wheels that run on the track cables are outside of the carriage frame, which is thus free to pass between the two saddles at the intermediate supports in which the track cables lie.

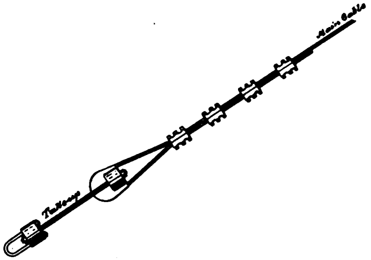
The plants may be either simple conveyors, such as used in transferring material across rivers or ravines, or they may partake of the nature of hoists also, and in this adaptation is found their widest application for quarry work, canal excavation, stripping, piling, dam building, levee construction, and other purposes, where derricks would be cumbersome or impracticable, on account of the limited area which they cover. The advantage, moreover, of having a clear space for the men to work in is one to commend our conveyors to quarrymen and contractors, to say nothing of their exemption from injury by flood, fire or explosions.

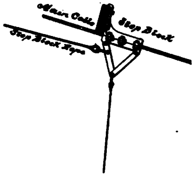
Lines adapted to hoist as well as convey the loads are of two types, one, applicable to inclines only, in which the carriage descends by gravity and but one operating or hoisting rope is used; the other, applicable to either horizontal lines or lines where the inclination is not sufficient for the carriage to descend by gravity alone, in which the hoisting and conveying are done by separate ropes. In either case the track cable rests upon saddles or grooved blocks of hard wood, forming the peaks of the supports, and is anchored firmly to the ground at each end, a turn-buckle or take-up usually being provided at one of the anchorages for maintaining the proper deflection. The supports are pyramidal towers of wood or iron, as preferred, although in many cases, especially when the loads do not exceed one or two tons in weight, these are simply A frames or masts guyed with wire ropes.

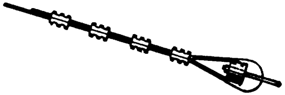
INCLINED CABLE HOIST-CONVEYORS.

Inclined cable hoist-conveyors have been used for a long time and quite extensively in the quarries of Pennsylvania and Vermont, and also for quarry work in other localities. The hoisting rope is operated from a drum with friction connections, and the common arrangement is to mount these with the engine and boiler on one bed plate. The loading and unloading is effected at definite points. If the loads are to be elevated from a quarry, for instance, a stop or buffer-block is clamped to the track cable at the loading point, which arrests the carriage in its descent, and allows the bucket, skip, or whatever appliance may be used for holding the load, to drop to the place of loading. The hoisting rope is reeved through the carriage and fall block with a sufficient number of parts so that the hoisting resistance is less than the resistance to traction. Applying power to the hoisting drum the load rises till the fall block encounters the carriage, when the latter proceeds to move up the line till the point of discharge is reached. Here it engages a latch clamped to the track cable, which prevents the carriage from running back while lowering the load. The power is thrown out as soon as the carriage engages this latch, and the lowering of the load effected by means of a


Main Cable
Main Cable
Counterweight
Carrier Rope
Hoisting Rope
Latch Block Rope
Stop Block Rope
Hoisting Rope
Carrier Rope
Carrier
Carriage
Stop Block Rope
Fall Block


Main Cable
Tail Rope

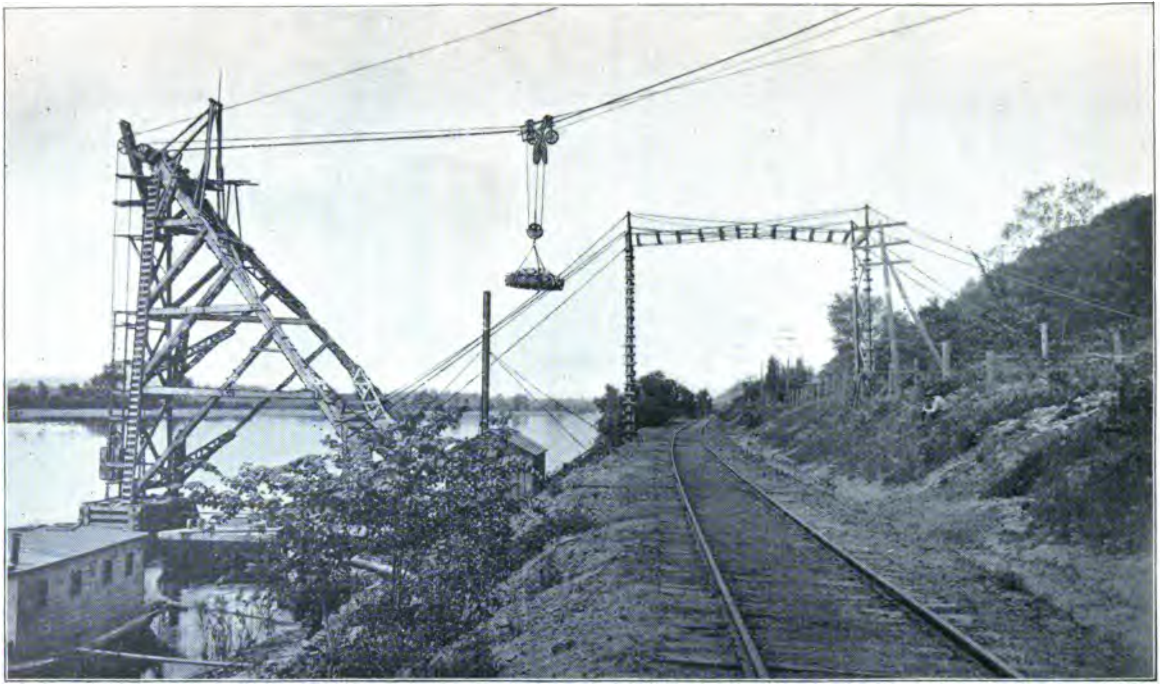

Main Cable
Stop Block
Stop Block Rope



brake on the drum. The latch and stop blocks are so designed that they can be shifted to correspond with varying points of loading or discharge. In some cases, where the upper point of discharge or loading is fixed, the carriage is held by a V-shaped frame, pivoted at the mast or support, and which is dropped over the carriage. The latter is freed by means of a light rope which hangs from the back end of this frame or latch, as the case may be, and descends by gravity, pulling the hoisting rope out with it. The limiting or least inclination on which such a line will work is about one in three. If the load is a descending one the operation is similar, but in this case lighter inclinations are practicable, the limit being a fall of about one in five for ordinary loads. The power required is considerably less, since this is only applied in raising the loads from the ground.

If it is desired to load and unload at various points along an inclined hoist-conveyor the carriage may be attached to an independent rope operated in conjunction with the hoisting rope, except when raising or lowering the load, when it is held by a brake on the drum from which it is driven. In this case an engine with two drums is required, of which there are two styles; one in which both drums are mounted side by side on one shaft, and the other in which the drums are mounted on separate shafts, tandem fashion, the back drum being elevated sufficiently so that the rope from this will not interfere with the forward drum. The special conditions of the problem will govern the choice of engine; the tandem drum arrangement being best adapted to short spans, where the hauling rope is sometimes operated from a spirally-grooved drum, the rope moving from one side of the drum to the other as the carriage travels back and forth.

The accompanying illustrations show views of the towers of such a line furnished the United States Government at Britts Landing, Wisconsin, for handling stone used in the improvement of navigation of the Mississippi River at that point. Upon completion of the work for which it was designed the line was dismantled and portions of it used in the construction of a similar line erected at La Crosse, Wisconsin. The clear span between the heads of towers at Britts Landing was 811 feet, the difference



INCLINED CABLE HOIST-CONVEYOR,
Built by THE TRENTON IRON COMPANY, Trenton, N. J.,
For the U. S. Government, at Britts Landing, Wis.
View of Lower Tower.

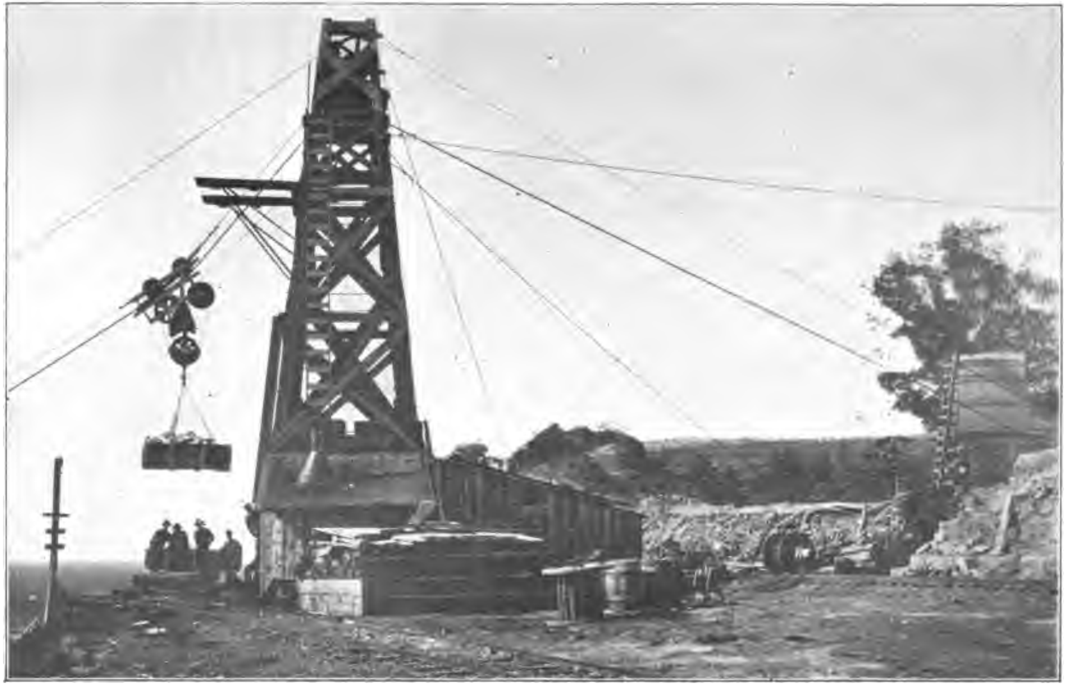
in elevation 387 feet, the head tower being 42 feet and the lower tower 70 feet from base to top.

A notable feature of this line was the absence of fall-rope carriers, which were found to be unnecessary. The view of the lower tower shows the carriage with loaded skip hanging from it, the latter being made of ¼-in. steel, measuring 7 ft. x 7 ft. x 2 ft., and weighing, loaded, a little over 12,000 lbs. The skip was suspended by three chains, the two side chains being equipped with ordinary hooks, and the front chain with a "knock-off" hook, which connected with a ring attached to the bottom. The method of discharging this skip was to lower it to the deck of the barge and disengage the front hook, so that in hoisting the skip hung empty from the two side chains, and was returned to the quarry in that position. The outside legs of this tower stood on a crib, which also served as an anchorage for the track cable. The crib was loaded with 90 cubic yards of broken stone, and the cable was anchored to the submerged part of the same by means of a 2-in. stud chain in two parts. The weight box shown back of the crib was weighted with 6000 lbs. of stone, and served as a tension weight for the rope that moved the carriage, the two ends of which were connected to the latter, making practically an endless circuit.

The view of the head tower shows the loaded skip lifted from the car and ready to be sent down the cable. The head sheaves, about which the hauling rope worked, were boxed in to avoid danger of injury while blasting in the quarry.

The track cable at this end was anchored to an oak log buried in the ground 190 feet back of the tower. A 2-in. stud chain was used for this purpose, similar to that at the other end. and between this chain and the socket on the end of the cable were a couple of take-up screws for regulating the tension of the cable. The track cable was 2-in. diameter, of the Patent Locked-Wire construction (see page 33) ; the hauling rope was ⅞-in. diameter, cast steel, 19 wires to the strand, and the hoisting rope ¾-in. diameter of the same kind.

The line was operated by a 10-in. x 12-in. double-cylinder engine, with reversible link motion and two drums arranged tandem fashion, the front drum being used for operating the hoisting rope and the back drum the



INCLINED CABLE HOIST-CONVEYOR,
Built by THE TRENTON IRON COMPANY,. Trenton, N. J.,
For the U. S. Government, at Britts Landing, Wis.
View of Head Tower.

hauling rope. This line exceeded the contract requirements and promises made for it as to cost of operation and maintenance.*

THE LAURENT-CHERRY PATENT HOIST CONVEYOR.

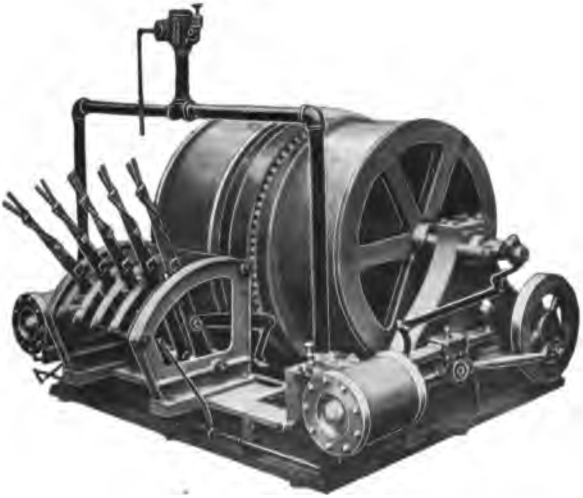
Owing to the steep inclination necessary for the successful operation of inclined hoist-conveyors, their application is confined to locations where the conditions are favorable. In most cases the terminal points are on about the same elevation, or the inclination is not sufficient for the carriage to descend by gravity, so that its movement must be effected by means of an independent rope and drum. The latter usually has a shallow concave rim, or semi-elliptic shape in section, about which the rope is wrapped a sufficient number of times to give the necessary frictional contact for driving; the rope running over and around sheaves in the towers, and the ends being attached to the carriage, which practically forms the completing link of an endless circuit. It is on account of this feature that such lines have come to be known as "Endless Rope" Hoist-Conveyors, or Cableways, and the best thing of this class is unquestionably the arrangement patented by Louis E. Laurent and Edward E. Cherry, the practicability and efficiency of which has been thoroughly demonstrated in a number of lines, among which may be mentioned one built for the United States Government at St. Paul, Minn.

THE DISTINGUISHING FEATURE OF THIS ARRANGEMENT IS THE ABSENCE OF FALL-ROPE CARRIERS, that have been necessary heretofore, on lines of this class, for supporting the hoisting rope, which would sag unduly when relieved of the tension due to the load, if not supported in some way. Moreover, with the carriage at certain points, the weight of the fall block alone would be insufficient to overhaul the rope, and would not descend if not relieved of the back pull due to the weight of the rope. The construction and relative merits of the different styles of fall-rope carriers that have been used is a matter it will not be necessary to consider; it is sufficient to know that the best of these are objectionable and a source of constant trouble.

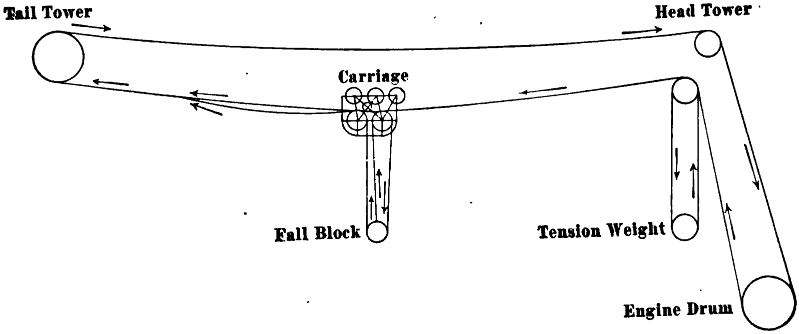
---

*See paper by R. D. Seymour, read before the Western Society of Engineers, April 7, 1897.

The Laurent-Cherry System in dispensing altogether with fall-rope carriers marks an advance in the capabilities of lines of this class. In this system, as in other hoist-conveyor plants of the kind, an engine with two drums, as illustrated herewith, is required; one for operating the hoisting rope and the other the hauling rope, or rope that moves the carriage. The hoisting rope in lines as heretofore constructed winds on an ordinary grooved drum, and is conducted directly through the fall-rope carriers and carriage to the fall block, and the hauling rope which works in an endless circuit is operated by an elliptic-faced drum. In the Laurent-Cherry System, however, both ropes are operated in endless circuits, and both the engine drums therefore have elliptic-faced rims. The arrangement of the hoisting rope is exhibited in the diagram on following page. Starting with the end which is fastened to the fall block, after making the necessary number of laps about the sheaves in the carriage and fall block, the rope is conducted to a sheave in the top of the tail tower, around this to a sheave in the top of the head tower, thence down to the engine drum and

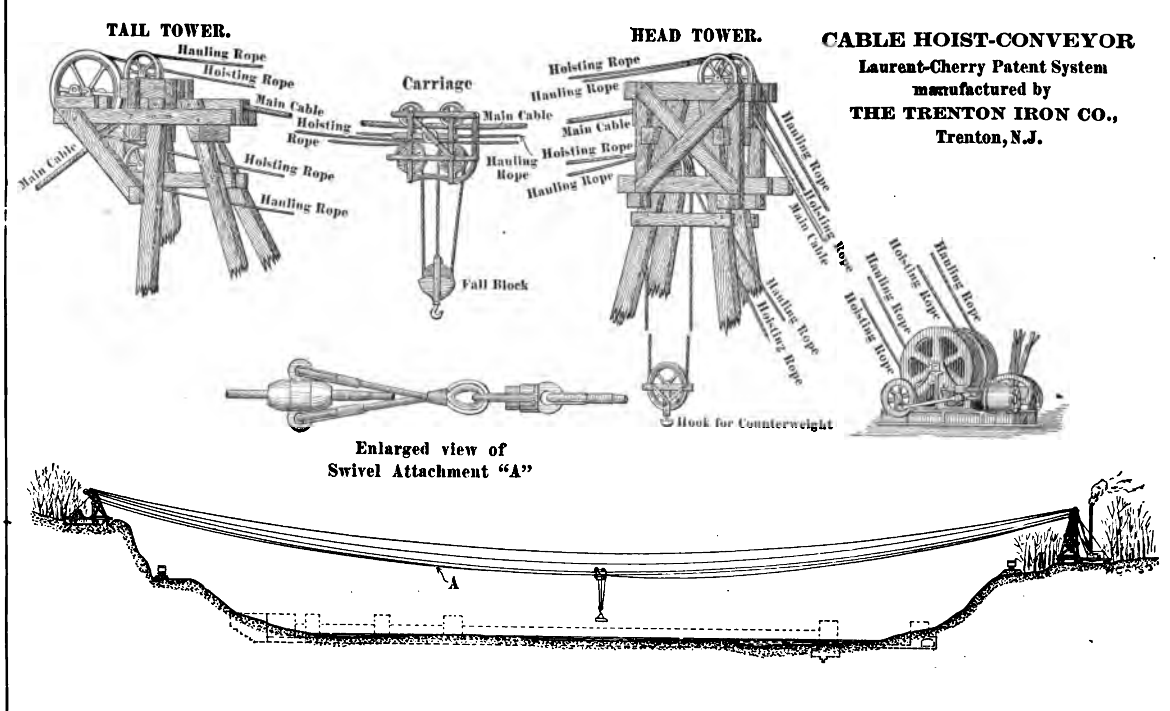


around this as many times as may be necessary, thence around a take-up sheave, by means of which a uniform tension is maintained, and back to a point on the rope itself between the carriage and the tail tower, where it terminates, and is secured by a patented double swivel attachment. The rope thus makes what is practically an endless circuit, to which a short piece is attached, but which in reality is simply the extension of one end, some 200 or 300 feet long, that terminates in the fall block, or long enough to allow for the greatest vertical lift, and yet not so long as to overbalance the unloaded fall block and prevent its descending.

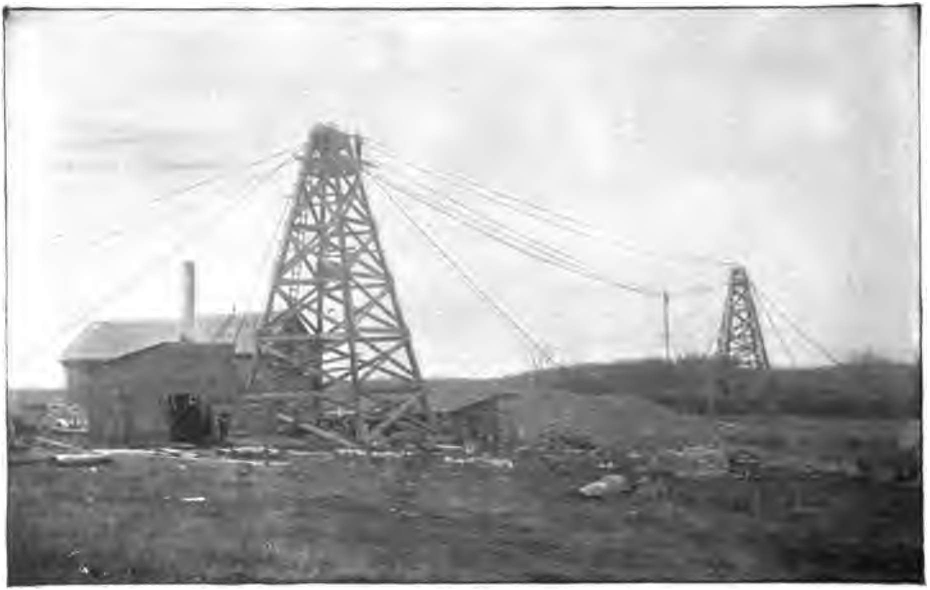


In thus dispensing with fall-rope carriers, the expense of maintaining these is not only obviated, but the wear and tear of the moving ropes is less, and it becomes practicable to move the carriage at a much greater speed, so that the capacity to handle a certain amount of material in a given time is correspondingly increased.

The engine drums are provided with brakes as well as power connections, so that each can be operated independently of the other. To move the carriage, both drums are put in motion ; in raising or lowering, however, the power is disconnected from the hauling drum and the brake applied to hold the carriage at the desired point, while the hoisting drum alone is operated. The hoisting or lowering is done at a speed corresponding to the number of times that the hoisting rope is lapped about



CABLE HOIST-CONVEYOR
Laurent-Cherry Patent System
manufactured by
THE TRENTON IRON CO.,
Trenton, N.J.



Span, 350 feet. Load, 4 tons.

CABLE HOIST CONVEYOR (Laurent-Cherry System),

Built by THE TRENTON IRON COMPANY, Trenton, N. J.,

For Cory & Laverdure, Peterborough, Ont., Canada.

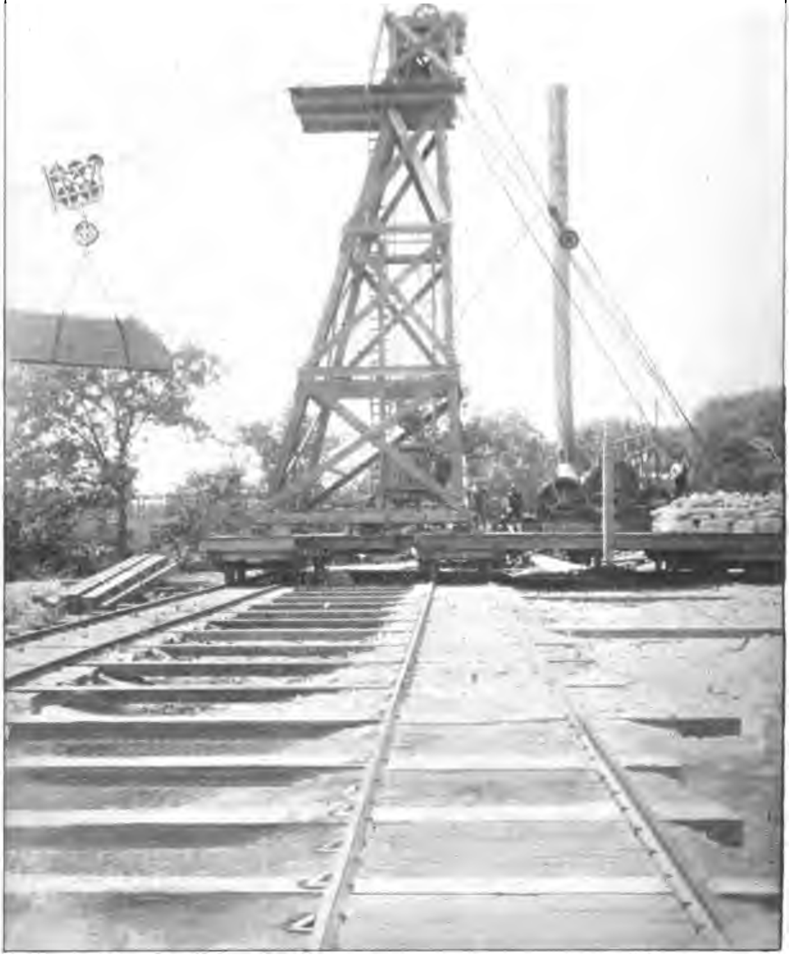
the sheaves in the carriage and fall block, the speed being inversely proportionate to the number of laps, or so-called "parts" of the rope.

A great advantage possessed by hoist-conveyors of this class is that loads may be raised or lowered at any point along the line.

The St. Paul plant, above referred to, is used in the construction of what is known as Lock and Dam No. 2, which is one of a series of four, designed for the improvement of navigation of the Mississippi River between Minneapolis and St. Paul, by the United States Government, under the direction of Major Frederick V. Abbot. The towers, it will be observed from the accompanying illustrations, are mounted upon trucks, so that the entire line can be shifted as the work progresses, and is similar in this respect to the cable hoists used on the Chicago Drainage Canal. The clear span between the towers is 1150 feet, the longest yet made with a movable plant. The head tower is 44 feet in height above the rails, on which the trucks run, and the tail tower, owing to the difference of level in the banks of the river, but 30 feet high.

The track cable is of the Patent Locked-Wire construction, 2-in. diameter, and is anchored to the outer ends of the platform by adjustable tackles, one of the blocks of which shows in the view of the head tower. The reason for anchoring the cable in this way was owing to the fact that the loading was nearly all done in one place, and it was therefore stipulated in the specifications that the arrangement must be such that the cable could be shifted occasionally in order to distribute the wear at the loading place over as great a surface as possible. The line is operated by an engine with 10-in. x 12-in. double cylinders, rated at 50 H. P., and is capable of handling a 5-ton load at a traversing speed of 800 feet per minute; in fact it has been run at a speed of over 1200 feet per minute without any appreciable vibration.

The hoisting and hauling ropes are of cast steel, ¾-in. diameter, 19 wires to the strand, of the ordinary lay. The large sheave just back of the head timbers of the tail tower (see illustration page 19), is one around which the hoisting rope passes. As the swivel connection has to pass around this sheave, it is made with specially wide flanges. In this particular case, however, the swivel connection would only touch this

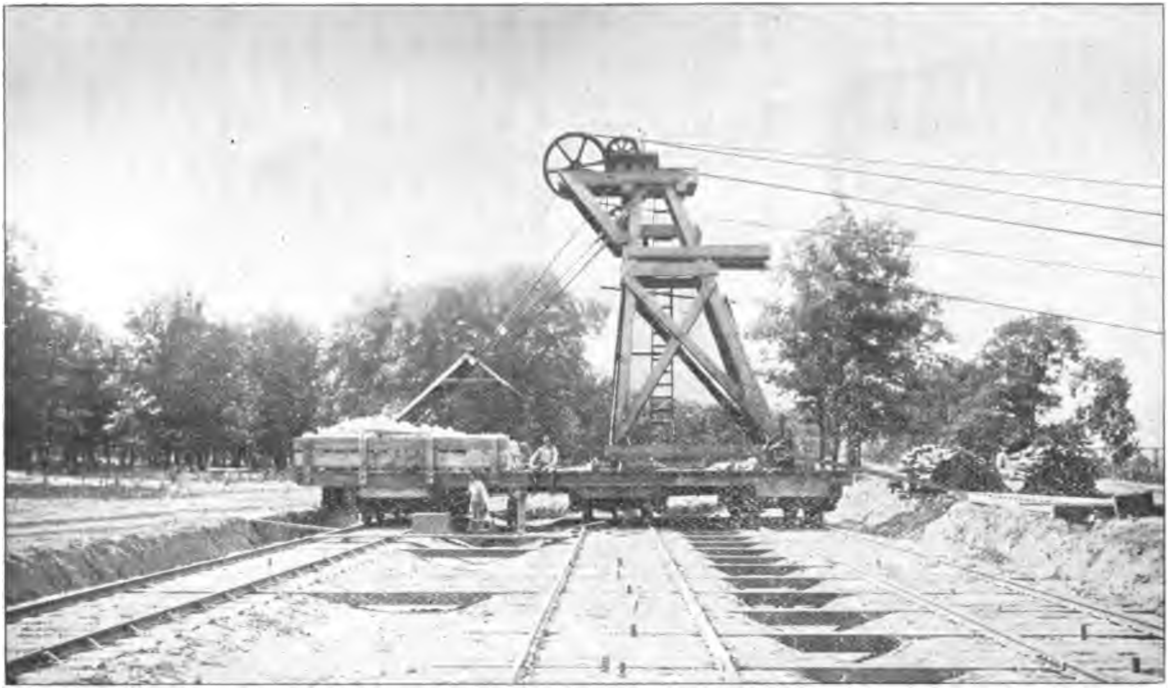


CABLE HOIST-CONVEYOR (Laurent-Cherry System),

Built by THE TRENTON IRON COMPANY, Trenton, N. J.,

For the U. S. Government, at St. Paul, Minn.

View of Head Tower.



CABLE HOIST-CONVEYOR (Laurent-Cherry System),
Built by THE TRENTON IRON COMPANY, Trenton, N. J.,
For the U. S. Government, at St. Paul, Minn.
View of Tail Tower.

sheave when the carriage is within 200 feet of the tail tower, which would be very seldom, as about 90 per cent. of the work to be done is in the middle of the span and near the east bank.

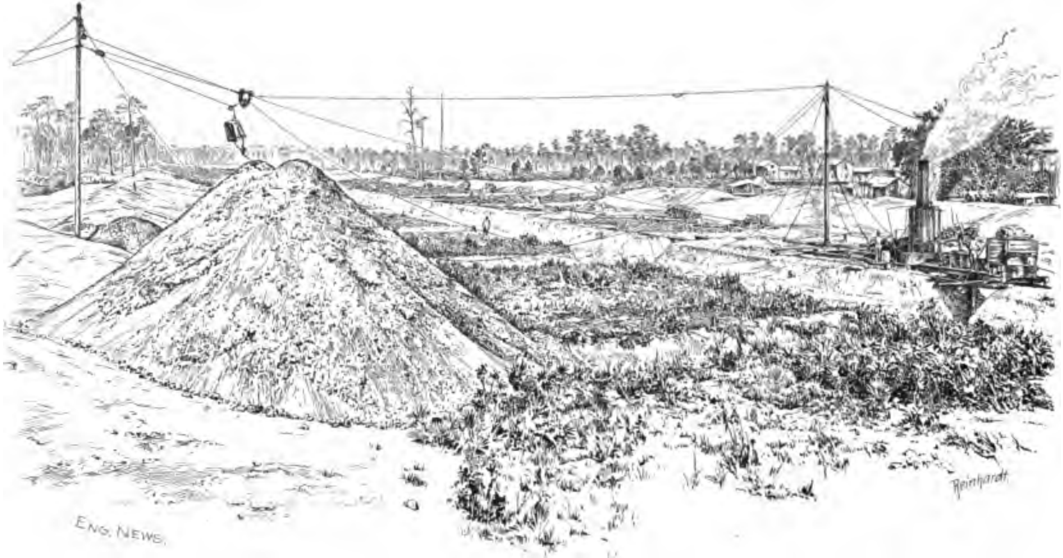
Maj. F. V. Abbot reports to Chief of Engineers under date of July 7th, 1900, in reference to the cableway, as follows: "The cableway has been in constant use for 16 hours a day during a large part of the working season and has given no trouble. It has paid for itself many times over in the saving of time effected by being able to lift full 7 tons and carry it from any part in the coffer dam to any point in the coffer dam or on the banks within the length of the tracks, 660 feet."

We also build lines to meet the special requirements for light and rapid work, which can be quickly taken down and set up again in new locations, and such lines have contributed largely to the economical working of the phosphate deposits of Florida.

THE HALL PATENT CABLE HOIST-CONVEYOR.

The Hall Patent Hoist-Conveyor is specially adapted to excavating canals and trenches, but may also be used in constructing levees and embankments, and is susceptible of being easily dismantled and re-erected.

As shown in the illustration, a mast is mounted upon skids alongside one bank of the canal, and another mast is erected firmly in the ground on the opposite side, about 200 feet distant. If a tree is convenient it may take the place of the latter mast. These two masts constitute the supports for the stationary cable, serving as a track for the hoist carriage, through which the operating ropes are lapped, and below which the bucket hangs. They are secured by guy ropes to stumps of trees or buried logs, commonly known as "dead-men." For convenience of description we will call the mast on the skids the power-station mast, and the opposite one the spoil-bank mast. The skids,upon which the power-station mast is mounted,consist of a couple of long, heavy timbers, and the mast is erected near one end of these at a point where two cross-timbers intersect or are framed into the skids, one at right angles and



HALL PATENT CABLE HOIST-CONVEYOR,

At work excavating the Suwanee Canal.

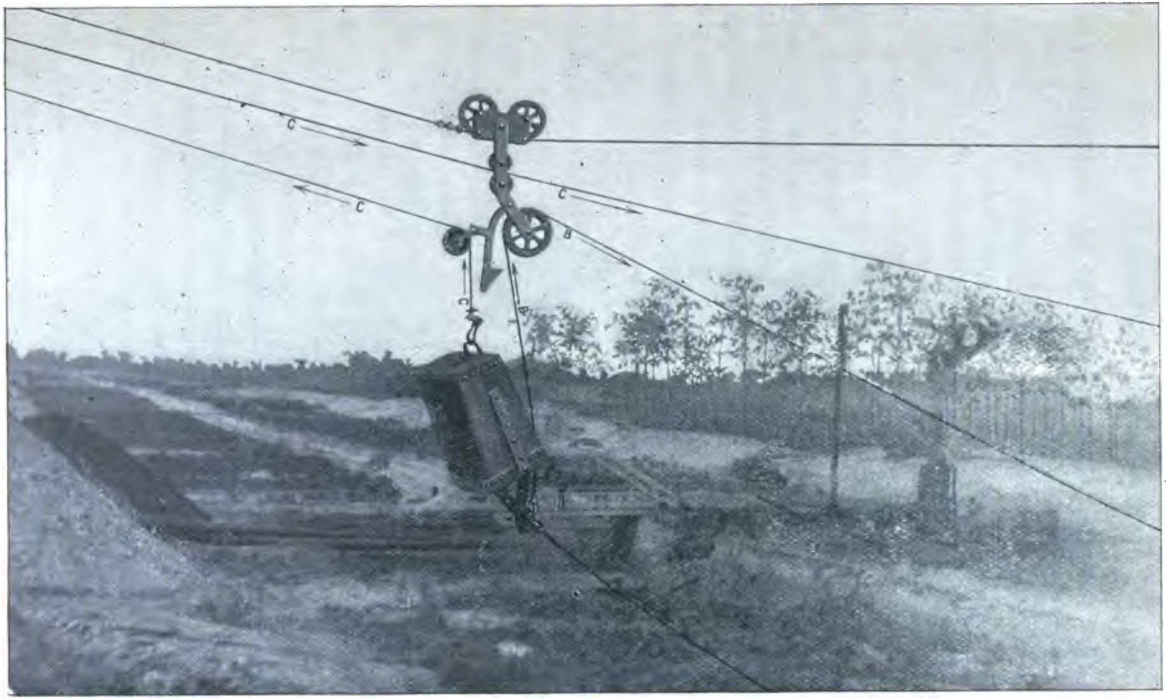
THE TRENTON IRON COMPANY, Trenton, N. J., Builders.

the other parallel with them, forming a cruciform base, to which is secured four short guy ropes, used to steady the power-station mast during the operation of shifting from one position to another, which will be described later. At the other end of the skids is mounted the engine and boiler for operating the line

One end of the track cable is fastened to a ring at the top of the power-station mast, and the other end, after being passed through a block attached to the top of the spoil-bank mast, is secured by a hemp-rope tackle to a "dead-man," tree or stump. The hemp-rope tackle serves the purpose of stretching the track cable to the proper tension for work, or letting it out during the operation of shifting.

The preferred form of engine is one with double cylinders, three drums placed tandem fashion, and an upright boiler, all mounted on one bed-plate. The drums are set at slightly different elevations, or in steps, as in the usual arrangement of hoisting engines of this type, the back drum being the highest and the forward drum the lowest, in order that the ropes from the middle and back drums may not interfere or come in contact with the drums over which they pass. The drums are driven independently of each other through friction connections, operated by hand levers, and are also fitted with brakes operated by treadles.

The rope from the back drum, which is used in the operation of loading the bucket and is known as the loading rope, A, (see illustration on following page) passes through a block at the top of the power-station mast, thence through a similar block anchored to a "dead-man" in the bottom of the canal, at a point some distance from the cable line, and thence to a fastening on the bail of the bucket. The rope from the center drum is used for hoisting, also for hauling in from the spoil-bank, and is known as the hoisting rope, B. It passes through a block at the foot of the power-station mast, and thence around a sheave in the hoist carriage to a fastening on the bail of the bucket. The rope from the forward drum is used in hauling the carriage out to the spoil bank, and is known as the out haul rope, C. It passes first through a block at the foot of the power-station mast, thence between idler wheels in the hoist carriage to a block at the top of the spoil-bank mast, through this to a



HALL PATENT CABLE HOIST-CONVEYOR.

Showing carriage and bucket.

block attached to the carriage, and thence to a link on the bottom of the bucket in the middle of one side.

The carriage consists of a pair of iron side plates, between which are two upper sheaves that traverse the carrying cable and a lower sheave around which the hoisting rope passes. The block, through which the out-haul rope passes, is attached to the hook-link.

The bucket tapers from the top down, and in shape is that of a truncated wedge. The bail is rigidly fastened to the body, and the link to which the end of the out-haul rope is fastened, as already stated, is at the bottom edge in the middle of one of the flat sides, the position of which is quite important, as will be better understood when we describe the operation of dumping. The upper plates on the flat sides are of crucible steel drawn to a knife edge and are fitted with teeth when necessary, so that the bucket may plough or cut its way readily through the material to be excavated.

The operation is as follows: Starting with the bucket in the bottom of the canal, directly under the cable line, and lying on one of its flat sides (it matters not which), the loading rope is put into action, dragging the bucket horizontally along the bottom until it scrapes itself full, when the engineer places his foot gently upon the treadle connecting with the brake of the loading drum, throwing out the power friction at the same time, and applying power to the hoisting drum, also just enough power to the out-haul drum to keep up the slack of the out-haul rope. The object of applying the brake to the loading drum is to bring the bucket into a vertical position before hoisting, and thus prevent the load spilling. As it comes back under the line, the engineer releases the brake on the loading drum, and allows the loading rope to run slack. The bucket is raised until the bail engages the hook at the lower end of the carriage, when the hoisting rope is released, and power applied to the out-haul rope, which takes the bucket out above the spoil bank. A stop block or bumper is attached to the main cable just above the dump, and when the carriage reaches a point within two or three feet of this bumper the steam is shut off entirely from the engine. The moment the carriage strikes the bumper (power being still applied to the out-haul rope), the hook disengages from the bail, when the out-haul drum is released of the power and the brake applied, which causes the bucket to swing back and at the same time turn upside down. It does so with a jerk, which very effectually clears it of its contents, but, to insure a good discharge every time, it is important that the bucket should fall flat side horizontal, and hence the reason for placing the link to which the out-haul rope connects, in the middle edge of one of the flat sides. After dumping, the steam is turned on, power applied to the hoisting drum and the brake gently to the out-haul drum. When the bucket reaches a certain point the power on the hoisting drum is released, the bucket drops, and at the same time moves forward, till it reaches the center of the canal, when a bumper on the track cable, similar to the one over the dump, arrests the motion of the carriage, and the bucket descends vertically into the canal. During this operation sufficient power is applied to the loading drum to take up the slack of the loading rope.

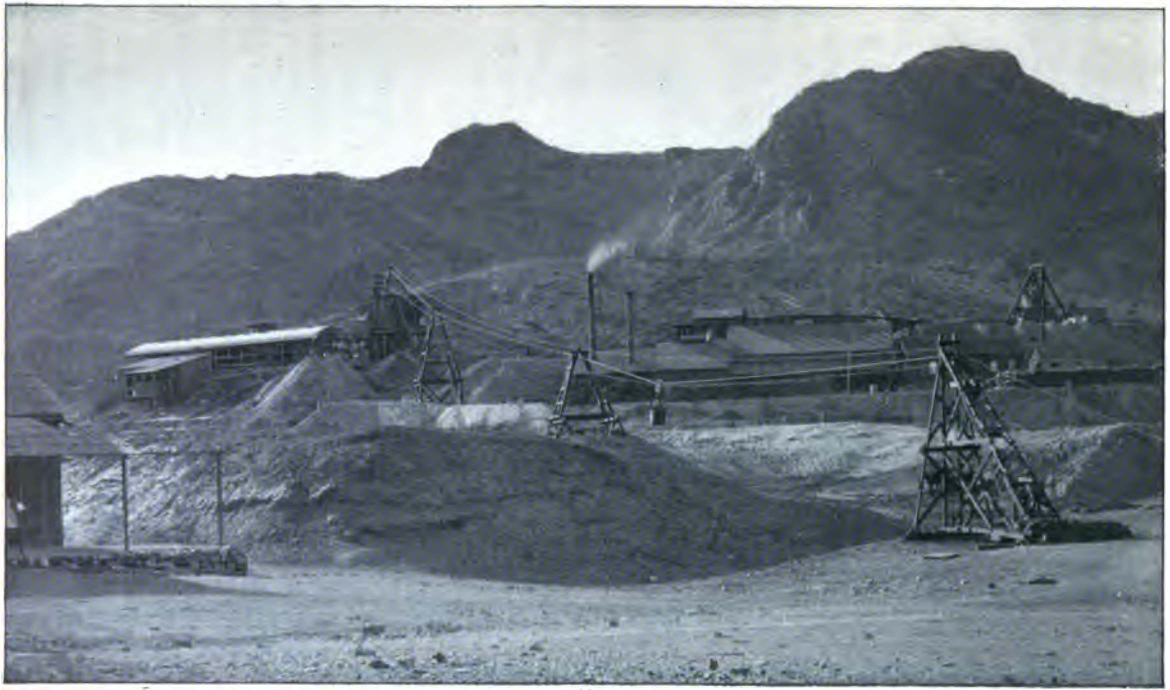
If it is desired to land the bucket for loading at a point not directly under the line, but some distance from it in a direction opposite to that in which the bucket is dragged in loading, so as to get a longer pull on it, which is frequently necessary to obtain a full load, especially after most of the loose material has been removed, it can be done in either of two ways.

First: The empty bucket is brought to a point within a few feet of the bottom of the canal, when the brake is applied to the hoisting drum and power to the loading drum, bringing the bucket up to a position where the hoisting rope makes an angle of about 45° to the vertical. The loading rope is then released, and the bucket swings back through the canal to the opposite side of the cable line, and upon reaching the extreme point of oscillation, the brake of the hoisting drum is let off, and the bucket drops to the bottom in the desired position for loading.

Second: By attaching a hemp rope to the link on the bottom of the bucket, passing it through a block anchored in the bottom of the canal on the side of the cable line opposite in direction to that of the loading-rope block, and thence to a winch-head on one end of the hoisting-drum shaft, and by this means hauling the bucket back to any desired distance within the reach of the other ropes. A plough is used in breaking up the bottom after it has become too hard for the bucket to fill easily.

The operation of shifting the apparatus from one position to another is performed in the following manner: The bucket is first deposited on the spoil-bank, and all the ropes lowered to the ground, the carriage having been previously placed so that it will drop in a convenient spot for oiling the bearings and otherwise overhauling it. The guy ropes are all loosened, the blocks in the bottom of the canal removed, the loading rope detached from the bucket, and pulled entirely out of the blocks through which it is lapped. Before loosening the ground guys, the shorter guys which anchor to the ends of the cross-timbers, at the base of the power-station mast are tightened. The ropes and tail block through which the out-haul rope passes are then disconnected from the spoil-bank mast and anchorage, and attached to a similar mast and anchorage, about fifty feet further on. A couple of blocks are attached to a dead-man about fifty or sixty feet ahead of the power-station mast, and a couple more to the skids near the foot of the power-station mast. Through these blocks the loading rope is lapped and the end properly secured. Power is then applied to the winding up of the loading rope, and the whole rig on the skids moves slowly forward. The distance moved at each shift is usually about twenty-five feet, two shifts of the power-station mast being made to one of the spoil-bank mast. The dead-men or stumps serving as anchorages for the various guys and blocks are prepared in advance while the work of excavation is going on. After the power-station is moved, the loading rope is lapped again through the blocks at the top of the mast, and in the bottom of the canal (the latter having been moved ahead to the anchorage prepared for it), and the end attached to the bucket as before. The mast guys are securely fastened to the anchorages prepared for them and hauled up tight; and, finally, the track cable is stretched into position, lifting the carriage and other ropes with it, and the work of excavating is resumed.

The operation of shifting requires from one to one and a half hours; and out of eleven working hours, three are consumed, on an average, in moving, oiling, making repairs, &c. The operation requires one en-



CABLE EXCAVATOR AND CONVEYOR,

Built by THE TRENTON IRON COMPANY, Trenton, N. J.,

For the Harqua Hala Gold Mining Company, Harqua Hala, Arizona.

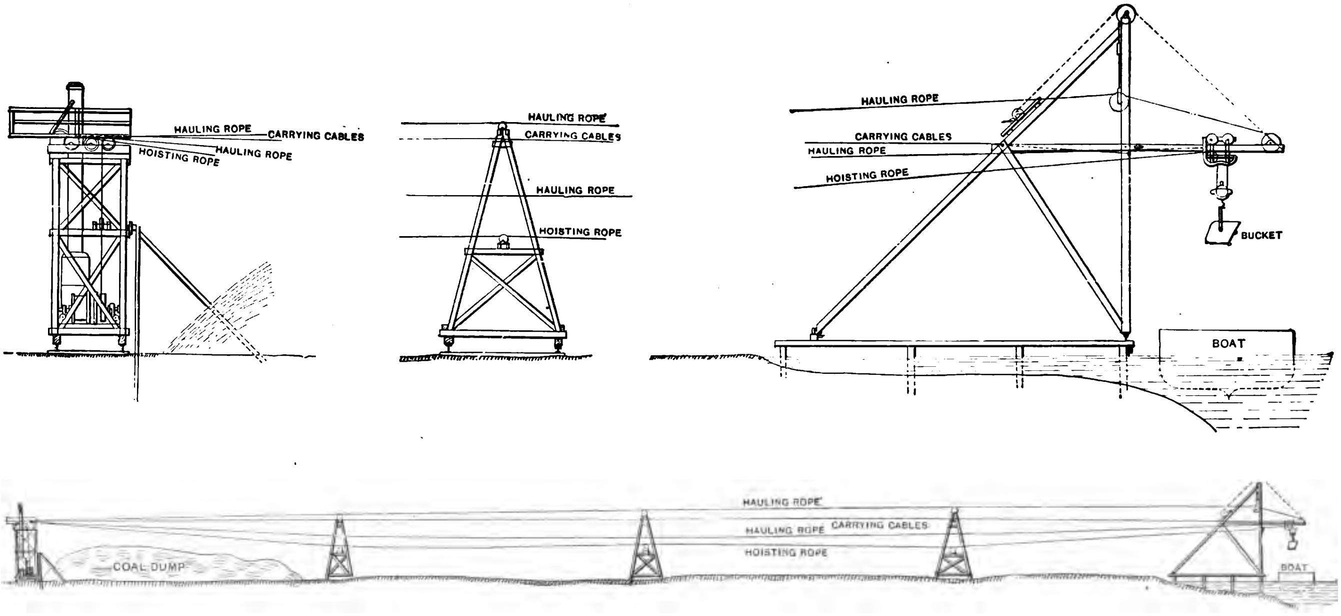
gineer, one fireman, one helper, and one other man who watches the bucket, signals the engineer and attends to other duties. A couple of men are employed in setting masts and preparing anchorages for the successive moves. The output is from 250 to 300 cubic yards per day for each line, according to the nature of the materials. The cost of operating is about $12 per day, including fuel and oil, or, taking everything into consideration, the cost is about six cents per cubic yard.

A modified form of the Hall rig was built for the Harqua Hala Gold Mining Company, of Harqua Hala, Arizona, to work a bed of tailings, as shown on the preceding page. This bed, including both the old and new tailings, covered a considerable and irregular area of ground, there being about 120,000 tons to be delivered to the leaching vats, at the rate of 150 tons per day, representing about three years' work. The problem was not only to hoist and convey this amount of material, but to build a line that would also be self-digging and portable; or, in other words, a line with a self-filling bucket, and with supports that could be moved radially about a stationary end support at the leaching vats, so as to work over the whole area without requiring hand labor. A further condition was that the line must be adapted to work in varying lengths, on account of the irregular shape of the bed, the longest distance being 825 feet.

The main trackway for the carriage consists of a ⅞-inch Patent Locked-Wire steel cable laid double; that is, at the stationary end support, just behind the bins, near the leaching vats, it passes around a sheave in a shackle, which is securely connected to a ground anchorage, and is stretched over the terminal and two intervening supports in two parallel lines; one end of the rope is rigidly fastened at the back of the movable end support, and the other end is coiled on a drum worked by a ratchet, sufficient cable being provided so that it can be paid out or wound up on this drum to suit the varying lengths in moving to different positions. The movable end support is firmly secured by guy ropes to posts. Below the carriage hangs the bucket of one-ton capacity, which is identically the same as that used on the Hall rig, and is operated by three ropes in a similar manner. The loading rope in this case, however, works parallel with the main cable instead of at right angles to it. This rope is attached directly to the bail of the bucket, and the main cable therefore is relieved from all strain during the operation of loading, which is the heaviest part of the work. The three ropes pass over sheaves at the top of the stationary tower in a pivoted shackle, which accommodates itself to the different angles at which the ropes must work, these ropes only being affected by the varying lengths of the line so far as to alter the amount of unused portions on the drums. How successfully the line does the work is best told in the words of R. M. Raymond, the manager of the Harqua Hala mines at the time, and under whose direction the line was built. In a letter dated August 13, 1895, Mr. Raymond says: "We consider the tramway most satisfactory and a great success. Nothing could suit our purpose better, and we are now able to run it up to full capacity. The way it gets down and digs in the sand is fine, and the whole arrangement is complete. It is so near being alive that if the engineer could be dispensed with and an automatic arrangement devised to keep the thing going, it would be the most wonderful hoisting arrangement in the field."

HOIST-CONVEYORS
FOR LOADING AND UNLOADING VESSELS.

On page 30 is illustrated a plant specially designed for stocking coal yards from masted vessels at a dock. Two Patent Locked-Wire cables, 1⅛-in. diameter, are stretched between the terminal structures and over intermediate supports about 100 feet apart, and constitute the trackway for the hoist carriage. The terminal structures and supports may be so mounted that they can be moved, or they may be permanent affairs, as desired. The main cables are anchored securely at the dock terminal, and at the yard terminal are wound on drums operated by a ratchet and lever, the latter being provided in order to relieve the cables of tension when shifting from one position to another. If the line is a fixture, these drums may be replaced by counterweights. The yard terminal structure supports the engine and boiler by means of which the line is operated, the



HOIST-CONVEYOR,

Built by THE TRENTON IRON COMPANY, Trenton, N. J.,

For loading and unloading vessels.

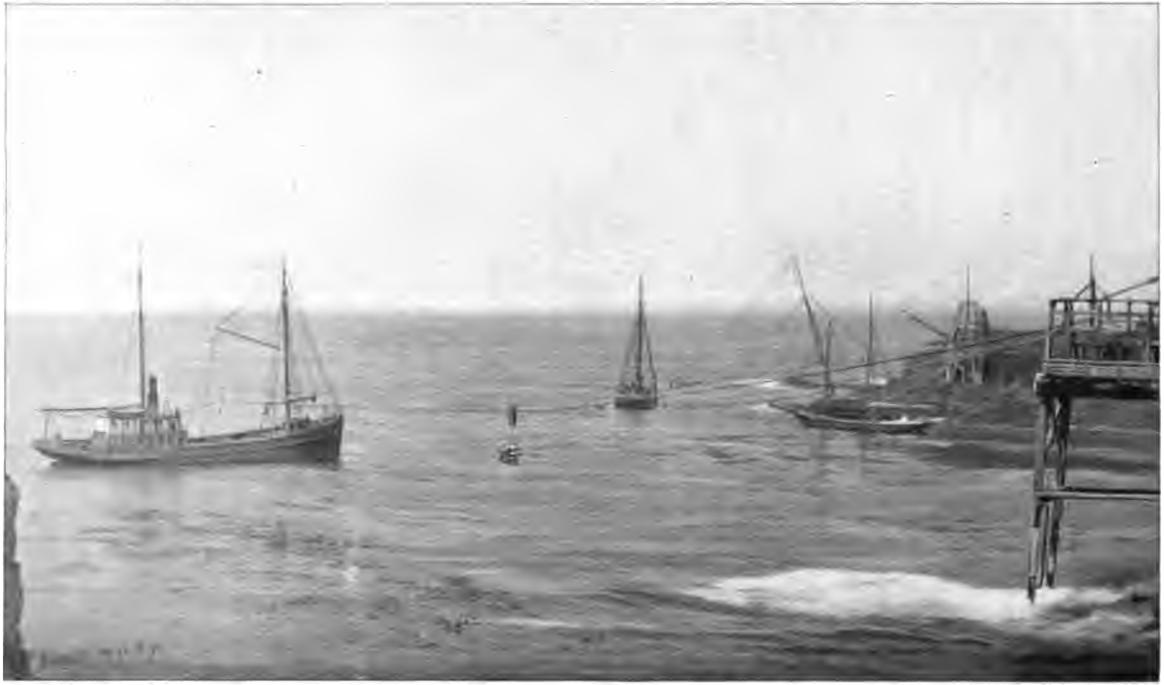
engine being similar to that used on other endless-rope hoist-conveyors.

In its special application to the unloading of coal, self-dumping buckets are used of the ordinary type, such as used in derrick work. There are two buckets in an outfit, each capable of holding a ton of coal, one being loaded while the other is taken over to the yard and back.

The boom at the dock terminal is hinged in such a way that it can be raised by a winch, provided for the purpose, in order to clear the rigging of the vessels while these are coming in or departing.

A special type of inclined hoist-conveyor, used extensively on the California and Hawaiian coasts, and known as a cable chute, is shown in the view of the line at the Gualala Mills Landing, Gualala, Cal., which also shows in the background the old style of derrick chute which has given place to the wire cable system.

The anchor for the main cable, weighing about 5,000 lbs., is attached to some 300 feet of 2-inch chain, and this chain to about 250 feet of 1½-inch galvanized iron rope, which is attached to the track cable by means of a hook and eye coupling. When shipping is interrupted for any considerable time, the ropes are uncoupled and the track cable coiled up on a drum at the shore landing. At such times the chain and iron rope lie in the bottom, with a light chain extending from the latter to a buoy, so that the end of the rope can be picked up again when wanted. As a precaution against accident to this chain, a similar chain and buoy are attached to the heavy 2-inch chain. The anchor lies in about 15 fathoms of water, and the vessel in about 12 fathoms. In the busy season the track cable is not taken in when a vessel gets through loading, but the two ropes are coupled together and cast off. Another vessel coming, picks up the ropes, uncouples them, passes the ends between the masts and couples them again; the track cable is then drawn up to a proper distance in the rigging, and the conveyor is ready for operation. Means for imparting the proper tension to the track cable are provided at the shore landing. Means are also provided here for holding the carriage while raising or lowering, and a grip or latch on the carriage itself prevents the load from falling in transit. The operating drum is mounted on an elevated stage or floor, which gives the brake-



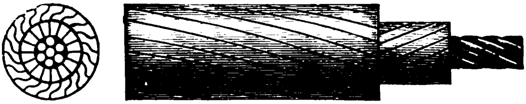
HOIST-CONVEYOR

at Gualala Mills, California, for loading vessels in open roadstead.

man a clear view of the entire line. Loads up to one ton in weight are carried, and the time of a round trip is two minutes, including time of loading and discharge, which corresponds to an output of 30 tons an hour. The carriage travels at a good speed down to the vessel, notwithstanding the fall is but 45 feet in a run of 550 feet.

THE TRACK CABLE.

The style of track cable used in hoist-conveyor plants herein described is known as the Patent Locked-Wire construction, as illustrated below, so named from the fact that the exterior wires interlock with each other in such a way as to present a smooth cylindrical surface like a solid round bar.



Patent Locked-Wire Cable.

This cable will not only outwear two to three of the ordinary kind, but, on account of its smooth surface, the life of the sheaves or rollers which run upon it is also proportionately greater, which is a matter of considerable importance.

The wires are made of the best tempered cast steel, and it is evident that with this construction such a thing as unstranding is impossible. Should any of the wires break, which rarely happens, it cannot result in projecting ends and a ragged surface as in the case of ordinary cables. Another advantage it possesses is that it has no tendency to twist in working, as ordinary cables have. These cables have wire cores, and on this account are somewhat stiffer than ordinary cables of the same size; but they are also much stronger. Compared with ordinary cables of equal strength, the Locked-Wire cable is quite as flexible. In the ordinary cables the strength is only about 80 per cent. of the aggregate strength of the individual wires, whereas in the Locked-Wire cable it is about 95 per cent., and in substituting the Locked-Wire cables for ordinary cables, therefore, a size smaller may be used.

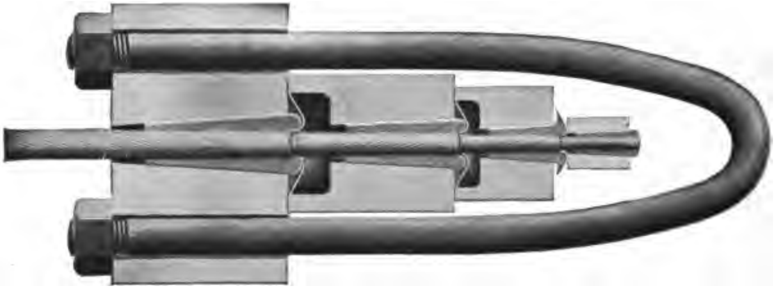
The following table gives the weight, strength, etc., of the different sizes:

Patent Locked-Wire Cable.

CAST STEEL.

Diameter, in inches.	Estimated weight per foot, in pounds.	Approximate breaking stress, in tons of 2,000 pounds.	Proper working load, in tons of 2,000 pounds.	Minimum diameter of drum or sheave, in feet.	Diameter, in inches.	Estimated weight per foot, in pounds.	Approximate breaking stress, in tons of 2,000 pounds.	Proper working load, in tons of 2,000 pounds.	Minimum diameter of drum or sheave, in feet.
2	10.00	170	34.00	...	1	2.50	43	8.60	7
1¾	7.65	129	26.00	...	⅞	1.88	36	6.60	6
1½	5.70	95	19.00	12	¾	1.38	27	5.40	5½
1⅜	4.75	80	16.00	10	⅝	0.90	19	3.80	5
1¼	3.80	67	13.40	9	9/16	0.72	13¼	2.65	4½
1⅛	3.15	55	11.00	8	½	0.57	11½	2.30	4

STEP SOCKET.



Our improved socket, known as the Step Socket, as illustrated above, is designed more especially for making attachments to our Patent Locked-Wire rope, and consists really of three or more sockets in steps, one behind the other, the larger for the outside wires, the following for the next larger, and so on down to the core. This style of socket can be relied upon in all cases to withstand any strain that the rope will safely bear.

Testimonials.

Trenton Iron Co., Trenton, N. J. LOUISVILLE, Ky., April 5th, 1899.

GENTLEMEN—Replying to your favor of the 31st ultimo. We have found the Patent Locked-Wire Rope superior to the ordinary rope, and the one we now have in use is giving entire satisfaction.

Yours respectfully,
DENNIS, LONG & COMPANY,
By E. P. Koetter.

Extract from a letter from W. I. STEEL, December 19, 1899, relating to an interview with DENNIS, LONG & CO.

"I called on these people and saw the cableway which you built. Our Patent Locked Rope is working fine. It was put in, I understand, in '93, and since then has carried on an average 400 tons daily, and the superintendent stated that from present appearances the rope was good for twenty-five years. This certainly is a recommendation for the Patent Locked Rope."

Trenton Iron Company, Chicago, Ill.: LEMONT, Ill., 5-13-1896.

GENTLEMEN—Your letter of the 6th inst., received upon the writer's return here.

In reference to the efficiency of the "Patent Locked Cable" furnished us by your Company, will say that results obtained by its use have been very satisfactory to us. We have conveyed an amount of over 80,000 cubic yards over this line with little or no perceptible wear on the cable.

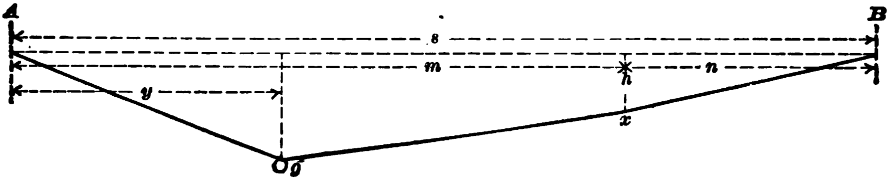
Very respectfully,
MASON, LOCHER & WILLIAMSON,
C. H. Locher.

To Whom it May Concern: ROCKLAND, Me., April 12, 1895.

This is to certify that we have hoisted fully one hundred and fifty thousand (150,000) tons of limestone over the Locked Cable Tramway, erected for us by the Trenton Iron Co., at our Engine Quarry. This output covers a period of about five years, and there is as yet no apparent wear upon the cable.

Yours truly,
COBB LIME CO.,
H. N. Pierce, *Sec'y.*

GENERAL FORMULÆ
FOR ESTIMATING THE DEFLECTION OF A WIRE CABLE CORRESPONDING TO A GIVEN TENSION.



Let s = the distance between supports or Span *A B;*

m&n= the arms into which the span is divided by a vertical through the required point of deflection x, m representing the arm corresponding to the loaded side;

y = the horizontal distance from load to point of support corresponding with m;

w = the weight of the rope per foot;

g = the load;

t = the tension;

and h = the required deflection at any point x;

all measures being in feet and pounds.

Then for **DEFLECTION DUE TO ROPE ALONE,**

$$h = \frac{m\,n\,w}{2t} \text{ at } x, \text{ or } \frac{w\,s^2}{8t} \text{ at center of span.}$$

For **DEFLECTION DUE TO LOAD ALONE,**

$$h = \frac{g\,n\,y}{t\,s} \text{ at } x, \text{ or } \frac{g\,y}{2t} \text{ at center of span.}$$

$$\text{If } y = \tfrac{1}{2}s,\ h = \frac{g\,n}{2t} \text{ at } x, \text{ or } \frac{g\,s}{4t} \text{ at center of span.}$$

$$\text{If } y = m,\ h = \frac{g\,m\,n}{t\,s} \text{ at } x, \text{ or } \frac{g\,s}{4t} \text{ at center of span.}$$

For **TOTAL DEFLECTION,**

$$h = \frac{w\,m\,n\,s + 2\,g\,n\,y}{2ts} \text{ at } x, \text{ or } \frac{w\,s^2 + 4gy}{8t} \text{ at center of span.}$$

$$\text{If } y = \tfrac{1}{2}s,\ h = \frac{w\,m\,n + g\,n}{2t} \text{ at } x, \text{ or } \frac{w\,s^2 + 2gs}{8t} \text{ at center of span.}$$

$$\text{If } y = m.\ h = \frac{w\,m\,n\,s + 2gm\,n}{2ts} \text{ at } x, \text{ or } \frac{w\,s^2 + 2gs}{8t} \text{ at center of span.}$$

Note.—*If the tension is required for a given deflection, transpose* t *and* h *in above formulæ.*

The Bleichert Wire Rope Tramway,

AND OTHER SYSTEMS OF AERIAL TRANSPORTATION.

Bleichert Tramway of the Bunker Hill and Sullivan Mining and Concentrating Company.
Showing long span across the town of Wardner, Idaho.

MANUFACTURED BY

THE TRENTON IRON CO.

TRENTON, N. J.

Engineers and Contractors and Sole Licensees in North America for the Bleichert System. Also, Wire Rope Equipments for Surface and Underground Haulage, Etc.

NEW YORK OFFICE—Cooper, Hewitt & Co., 17 Burling Slip.
CHICAGO OFFICE—1114 Monadnock Building.

Illustrated book, describing the above, will be mailed upon application.

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CALIFORNIA

THE APPLICATION

OF

WIRE ROPE

TO

Haulage, Shafts & Inclined Planes

By WILLIAM HEWITT, M.E.

THE TRENTON IRON COMPANY
Trenton, N. J., U. S. A.

1902

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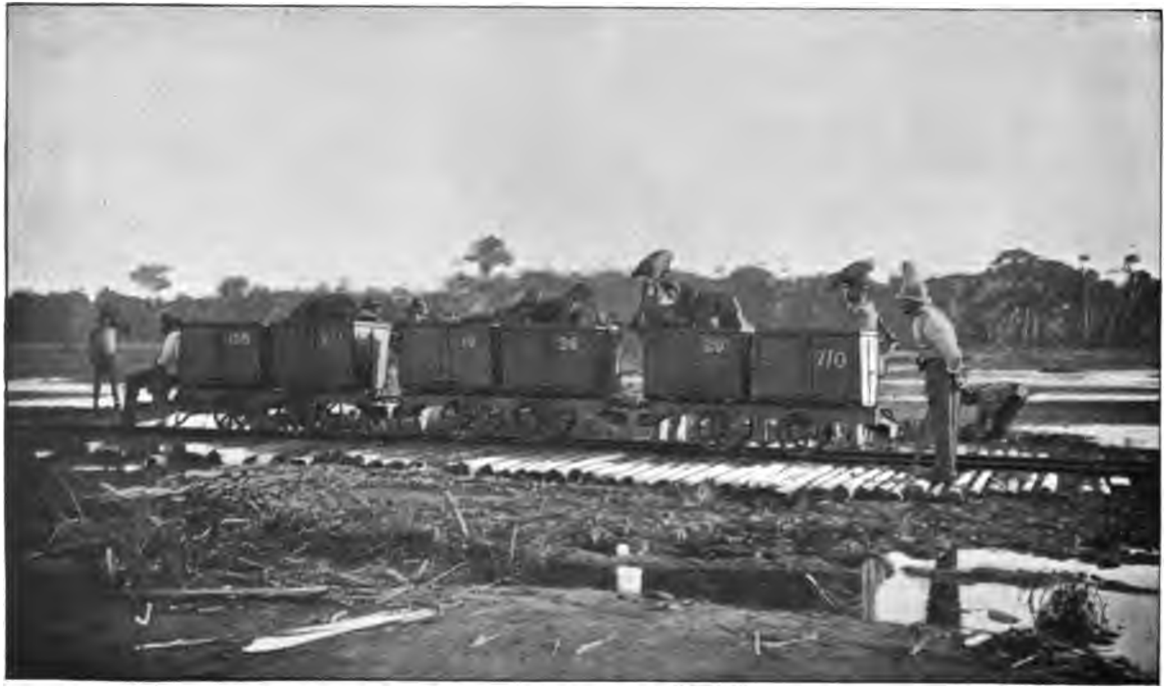
THE BRANDT PRESS, TRENTON, N. J.

Trenton Iron Co.



ENDLESS ROPE HAULAGE,

Built by THE TRENTON IRON CO., Trenton, N. J.,

For the Trinidad Asphalt Co., La Brea, Trinidad. View of Pitch Lake.

Surface and Underground Haulage.

ALTHOUGH animal power may continue to be employed to a certain extent for haulage purposes in mining and other operations, as the distances and capacities increase, so that the cost becomes a serious matter, it is bound to give way to steam power, either directly by means of locomotives, or through the agencies of wire rope and electricity.

The ease with which wire rope can be led in any direction, and over any grades, its comparative safety, high efficiency, and its freedom from the smoke and gases of steam locomotives, so deleterious to the health of the miners in confined operations, has brought it into general use for the underground haulage of coal and ores, as well as on inclined planes and shafts, for conveying the same to the surface or place of shipment as the case may be.

While electricity may be better adapted to passenger traffic on street and suburban railways, and seems to be rapidly superseding locomotives and wire ropes for this purpose, it is doubtful if it will ever replace wire rope to any great extent in mining operations, and more especially on underground lines, where dust and moisture have to be contended with, and where the skill and special tools required for repairing the delicate mechanism of electrical appliances are not immediately accessible.

There are two distinct methods of haulage by means of wire rope to be considered—one, known as the "tail rope," and the other as the "endless rope" system.

TAIL ROPE SYSTEM.

The tail rope system is one by which the haulage of the loaded cars is accomplished with one rope, termed the main or haulage rope, while the empties are drawn back by a separate and usually lighter rope, known as

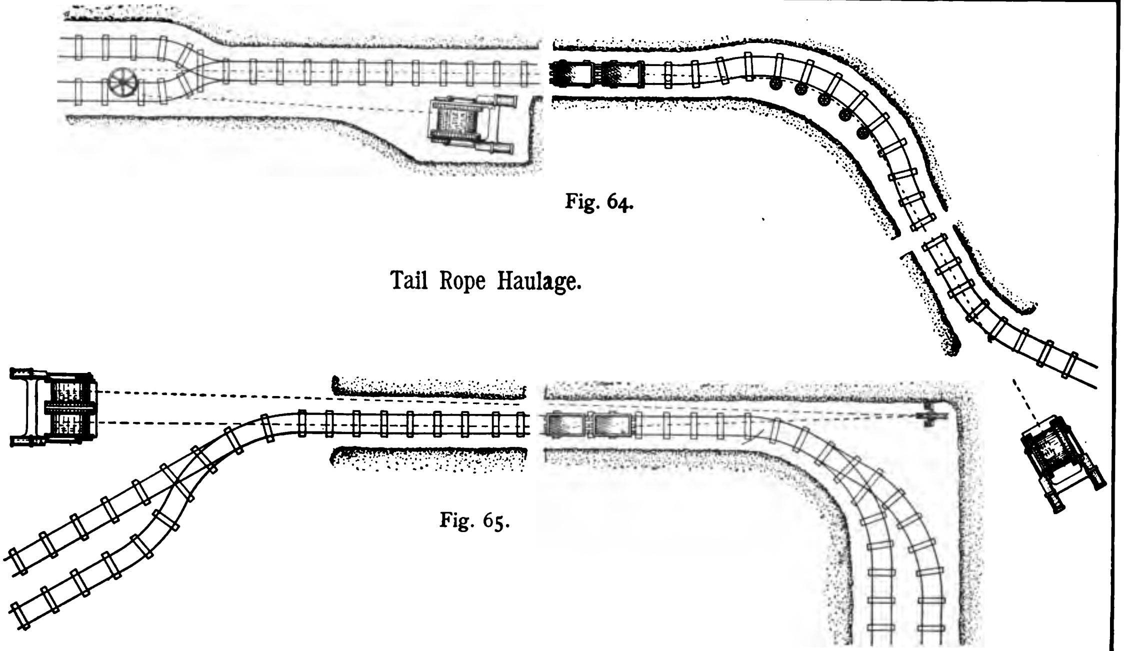


Fig. 64.

Tail Rope Haulage.

Fig. 65.

the tail rope, although where the grades favor the loaded cars, cases frequently occur where it is necessary to use a tail rope as large or even larger than the haulage rope. The sizes and kinds of ropes best adapted to the purpose in any case, will be determined by the load stresses and the degree of bending that they are subjected to.

The two drums with the engines for operating these ropes may be located at each end of the line, as in Fig. 64, or preferably located at the mine entrance, and driven by one engine, as in Fig 65. The latter is the usual arrangement, and, while requiring more tail rope, it enables a line to be operated by one engineer, besides permitting the erection of the engine outside of the mine, which is always desirable. The drums are driven by means of friction or clutch connections, usually through gears, but sometimes directly, so that while either drum is driven, winding up the haulage or tail rope, according as loaded or empty cars are hauled, the other drum revolves freely, paying out the rope on it. The drums are fitted with brakes in cases where the grades render them necessary. Fig 66 illustrates the ordinary type of tail rope engine, in which it will be observed the drums are mounted with the engine on one bedplate. Two independent lines are often operated by one engine, in which case four drums, as shown in Fig. 67, are arranged to be worked by one man.

The track rollers for supporting the ropes are usually made of hardwood (see page 56) spaced according to the contour of the ground, from fifteen to thirty feet apart, although iron rollers are frequently used to advantage, especially at points where the wear is heavy. At the end of the main line is the tail sheave, from four to five feet in diameter, around which the tail rope works, and a similar sheave is located at the end of each branch line. Between the main tail sheave and the mine entrance, and along the branch lines as well, the tail rope is carried upon small sheaves or rollers, generally of iron, at an elevation of three or four feet above the track, between timbers, along one side of the gangway, as shown in Fig. 68.

Curves may be made at any angle and of comparatively small radii, but where the radius is less than sixty feet, the trips should be taken around the curve at a moderate speed. The ordinary speed at which the

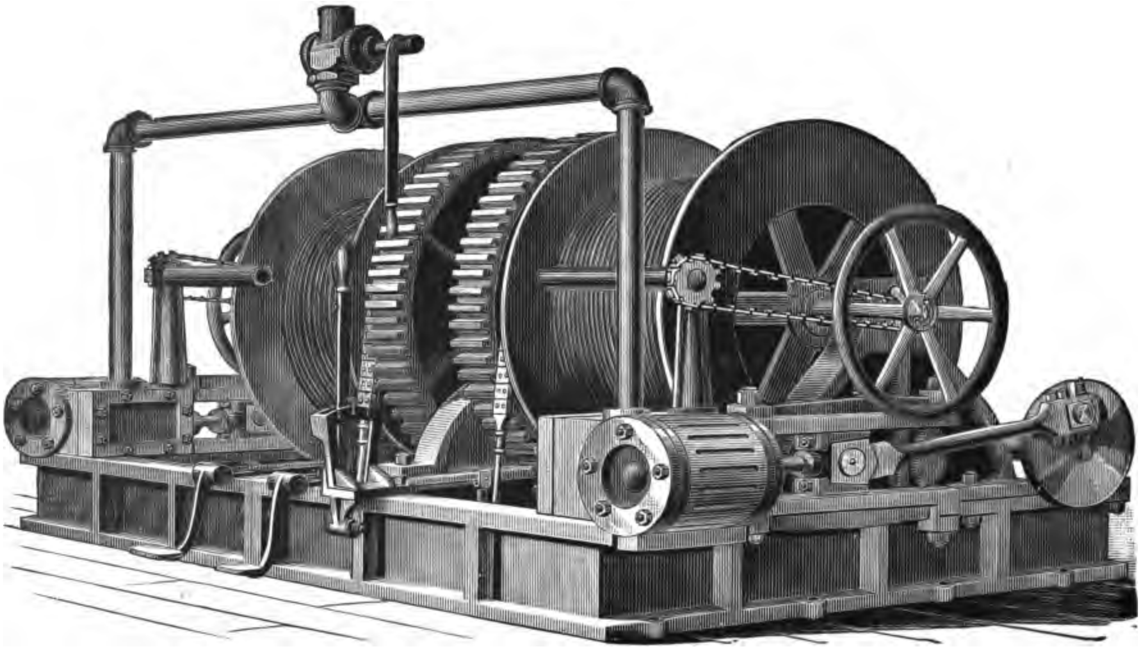


Fig. 66. TAIL ROPE ENGINE WITH TWO DRUMS.

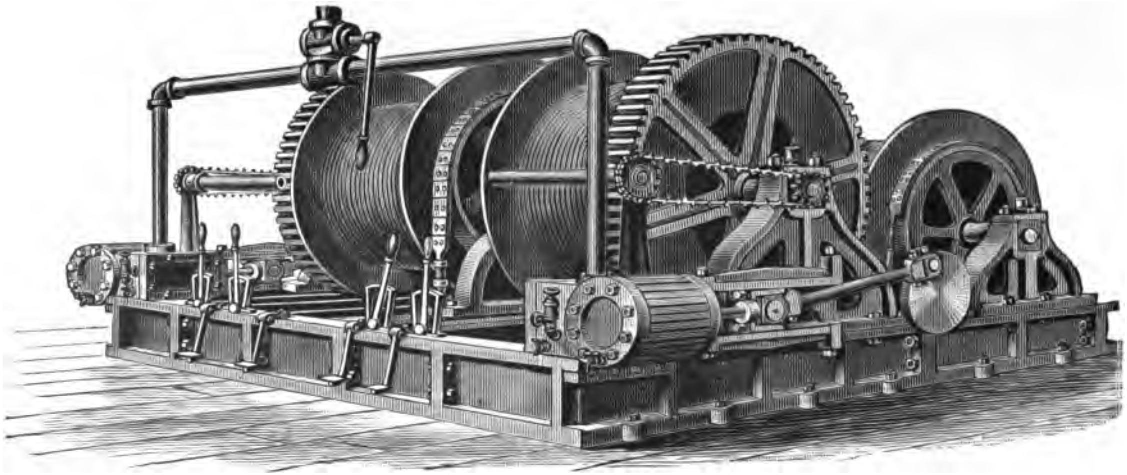


Fig. 67. TAIL ROPE ENGINE WITH FOUR DRUMS.

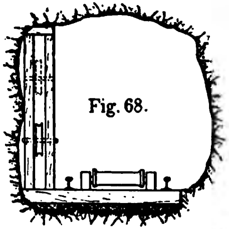
ropes may be run varies from eight to twelve miles an hour. The number of cars composing a trip depends largely on the grades, and varies usually from twenty-five to fifty. In some mines, however, as many as a hundred cars are handled at one haul.

Couplings are provided in the tail rope, by means of which the proper attachments may be made with the various branch ropes, which simply complete the tail rope line on their respective entries. In taking a trip into any side entry therefore, it is understood the branch ropes on the other side entries, as well as that portion of the tail rope on the main gangway, which is disconnected for the time being, lie idle. There are three methods of attaching the branch ropes, as illustrated in Figs. 69, 70 and 71. In the first two the change is effected when the trip reaches the junction of the main and branch ways, and in the last when the trip is at the entrance or shaft.

In the first arrangement, Fig. 69, a sheave is fixed near the roof or under the track, around which one end of the branch rope passes. In going in, the rope end *C* replaces *D*, on the front end of the train, and the end E replaces F in the tail rope. In the arrangement illustrated in Fig. 70, the tail rope always remains entire; the end *A* replaces *B*, and the latter end, being pulled in a little further, is attached to *N*.

In changing the ropes by the method illustrated in Fig. 71, a different course entirely is pursued. The branch ends are changed by a boy while the trips are being made up at the entrance or shaft, the couplings in the tail rope being set to come opposite the loose ends of the branch rope, as shown, when the ends *X*, *X* are replaced by *Y*, *Y*. This plan is much more expeditious than either of the others, since no time is lost in changing the ropes, as they are generally ready at the branch before the trip at the entrance is ready to be taken in, and the change is made while the ropes are free of stress. In the first two methods there is a loss of time, not only by reason of the additional stoppages at the branch, but also due to the fact that the trains usually arrive at the branch with the ropes under considerable tension. This makes it necessary very often, in changing the ropes, to use a winch to bring the ends together. A wooden clamp, fixed at one side of the entry, is sometimes used to

Fig. 68.



Track and Tail-Rope Rollers

Fig. 69.

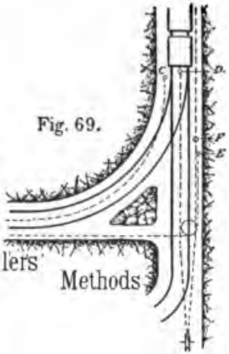


Fig. 70.

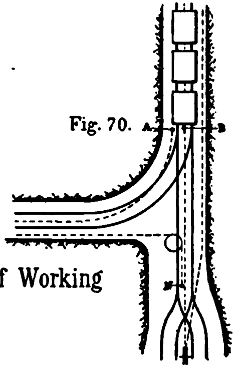
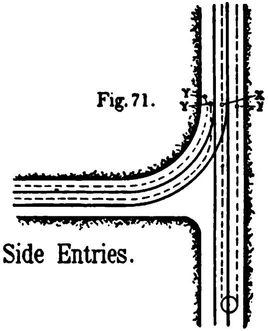


Fig. 71.



Methods of Working Side Entries.

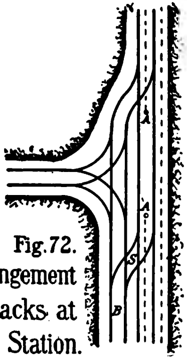
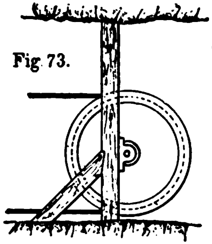


Fig. 72. Arrangement of Tracks at Side Station.

Fig. 73.



Vertical Tail Sheave

Fig. 75.

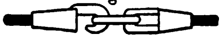
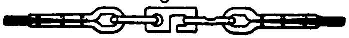


Fig. 77.



Various Styles of Tail-Rope Couplings.

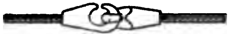
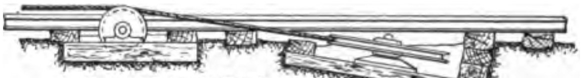


Fig. 76.



Horizontal Tail Sheave.

Fig. 74.

hold the tail rope while the branch rope is being attached, the clamp being applied before the tail rope is released, which prevents it from springing back.

The usual arrangement of tracks at entries on either side of a main or branch line is illustrated in Fig. 72. The ropes are knocked off the empty train in going in at the points *A*, *A*, opposite to which is the train of loaded cars ready to go out. A gentle fall in the track causes the empty train to run forward over the switch *S*, on to the siding *B*.

Fig. 75 represents a common style of tail rope coupling, which is simply a hook and loop socket connected by a link. The link may be dispensed with by using two hook sockets, that go together like the hooks of a bell-cord, as shown in Fig. 76. This is safer where the tail rope is likely to become slack at times. Fig. 77 represents another style of connection, where two strap sockets, with a single link in each, are connected by a flat steel hook attached to one of the links as shown. The opposite link has a notch in it through which the hook is passed, the opening being just wide enough to slip over the link at this point.

To uncouple the ropes while under stress, it is necessary to use peculiar hooks, known as "knock-off" hooks. There are various styles of these, the most common of which are illustrated in Figs. 78 to 83. Their operation will be readily understood by a glance at the illustrations. Fig. 83 represents a self-acting knock-off hook. When the train arrives at the point where the rope should be released, a bar of iron fixed at the proper point comes in contact with the bell-crank lever lifting the chains connected with the knock-off hook, and releasing the rope. These hooks are applied both to the main and tail ropes.

In mines which have been opened by vertical shafts or steep inclines, the tail rope system of haulage operates only to bring the cars to the foot of the shaft or incline, whence they are hoisted in elevator cages to the surface. Under these circumstances the tail rope engine may be placed either at the foot of the shaft or at the surface, as may be deemed most desirable. The latter position is preferable, notwithstanding the extra length of ropes required, owing to the advantage of having the engine outside where it is lighter, and repairs can be more readily made.

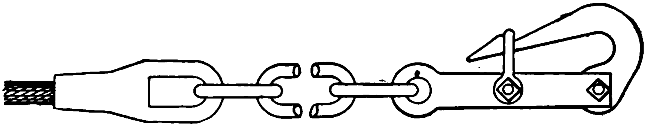


Fig. 78.

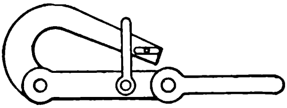


Fig 79.

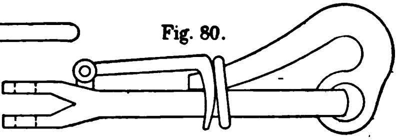


Fig. 80.

Various Styles of Knock-Off Hooks.

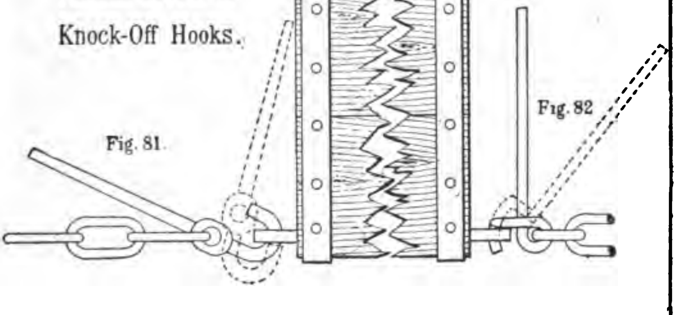


Fig. 81.

Fig. 82

Self-Acting Knock-Off Hook

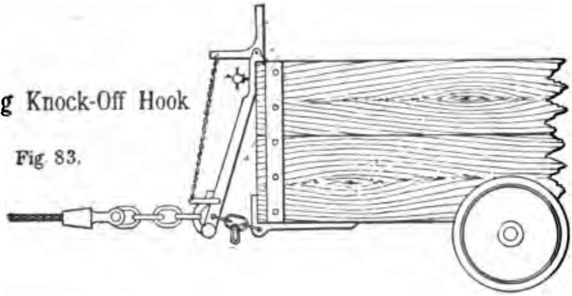


Fig. 83.

If the slope into the mine is an easy one, the trips may be hauled directly out, by providing an engine of sufficient power, and if at the same time the grade is steep enough for the empty trips to descend by gravity, the tail rope connections may be made at the foot of the slope.

Where the slope from the mine entrance to the tipple is in favor of the loaded trips, these may be lowered directly by means of the tail rope, the main rope being knocked off as soon as the trip comes out of the mine. In fact, a variety of conditions may occur to modify the character of the line and method of operating; the grades being a most important feature in this consideration. In laying out and estimating on any line, therefore, the importance of having an accurate profile to work to is manifest.

ENDLESS ROPE SYSTEM.

The endless rope system, as the name implies, is one by which a single rope is operated continuously in an endless circuit, the engine being fitted with a fly-wheel and governor, and requiring but little attention.

The engine drums, two in number, are from four to eight feet in diameter, placed tandem on horizontal shafts, and usually mounted on one bedplate with the engine, as shown in Fig. 84. The rope is lapped a sufficient number of times about these drums to give the necessary frictional adhesion, the drums being grooved according to the number of laps. The engine is geared to the back drum, while the forward drum, which is mounted in a position inclined sufficiently to lead the rope to the successive grooves of the driving drum, usually revolves freely in its bearings, although this drum is sometimes also geared to the engine.

The cars are attached to the rope by means of clutches or grips, either singly or in trains of two or more, according to the grades and number of tributary entries. The successful operation of the endless rope system depends largely on the effectiveness of the grips, of which a variety have been devised, and which of course must be proportioned to the load stress that they are subjected to.

We make a grip illustrated in Fig. 85 that has given very good satisfaction. It consists of a cast-iron bearing plate, in which the grip jaws

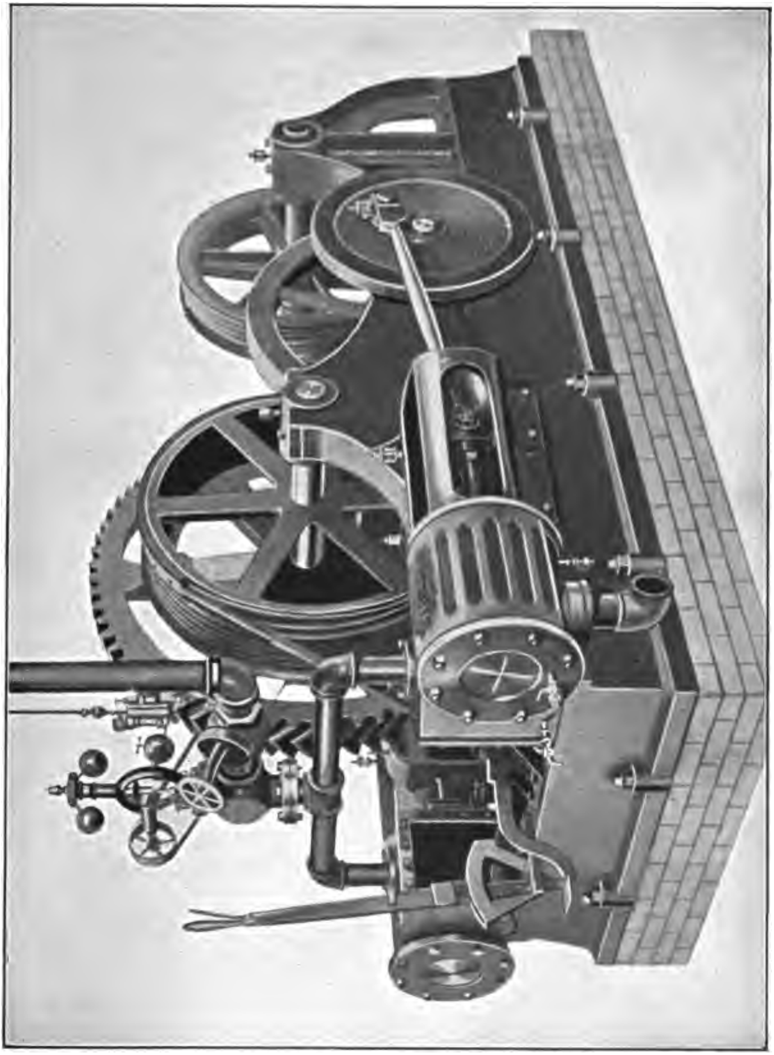


Fig 84. ENDLESS ROPE ENGINE.

oscillate on gudgeons sufficiently to give the necessary lateral movement in going around curves. The bearing plate is attached rigidly to the front or rear cars, according to the direction of the pull, and the jaws are operated by a rod, with a hand-wheel on the upper end and a screw-thread on the lower end, which moves the lower jaw up or down, clamping or releasing the rope, as desired, the upper jaw being at a fixed distance from the gudgeons on which it oscillates. The lower jaw is fitted with removable steel plates, which can be readily renewed as they are worn out. This grip is used by the Trinidad Asphalt Company for hauling the cars in an endless rope line over the pitch lake on the Island of Trinidad, a view of which is shown in the frontispiece.

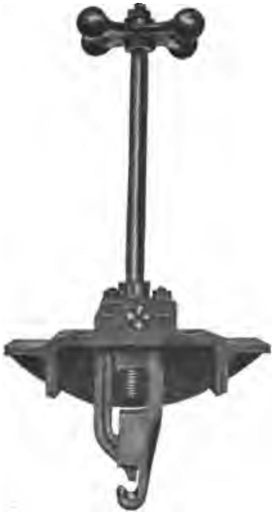


Fig. 85.
Endless Rope Grip.

Where the grades are variable, special cars are sometimes used for operating the grips, especially in cases where the stress is too great for the ordinary hand grips. In such cases the lateral movement is provided for by attaching the grip to a plate pivoted at the back end of the car, which is also fitted with brakes for relieving the grip of some of the pressure on the down grades. In most cases, however, the grip illustrated in Fig. 85 will answer the purpose, and if the grades should be such at any point as to cause the rope to lift the end of the car to which it is attached, or to tip it by reason of the downward pressure, this difficulty can readily be overcome by adapting the grip to replace a coupling in the train, thus adding to it the weight of a car and holding it more firmly.

The tension of the rope in lines of this class should be such as not to subject it to an undue stress, or pull the cars off the track in going around the curves, and the number of laps required therefore on the driving drum or drums, as the case may be, will be determined accordingly.

The tension may be applied at either end, but preferably at the end where the line is driven, as in Fig. 94, page 23, in which case the tension-sheave is mounted vertically on a carriage or slide actuated by a counterweight. When applied to the tail-sheave, this is mounted horizontally, as in Fig. 91, page 22.

To avoid slipping of the rope on the driving drum or drums, a certain ratio must exist between the tensions of the taut and slack portions, which is determined by the formula,

$$T = S e^{f n \pi}, \text{ or } T + S = \frac{e^{f n \pi} + 1}{e^{f n \pi} - 1} (T - S),$$

in which T and S represent respectively the tensions of the taut and slack portions; n, the number of half laps on the drum or drums geared or otherwise connected to the engine; f, the co-efficient of friction; e, the base of the Naperian system of logarithms $= 2.71828$; and $\pi = 3.1416$.

The following are some of the values of f:

Dry rope on a grooved iron drum,	.120
Wet " " " " "	.085
Greasy " " " " "	.070
Dry " " wood-filled sheaves,	.235
Wet " " " " "	.170
Greasy " " " " "	.140
Dry " " rubber and leather filling,	.495
Wet " " " " " "	.400
Greasy " " " " " "	.205

The values of $e^{f n \pi}$ and $\frac{e^{f n \pi} + 1}{e^{f n \pi} - 1}$ corresponding to the above values of f, for one up to six half-laps of the rope, are as follows:

Values of $e^{fn\pi}$

$f=$	n = number of half-laps on driving drum or drums.					
	1	2	3	4	5	6
.070	1.246	1.552	1.934	2.410	3.003	3.741
.085	1.306	1.706	2.228	2.910	3.801	4.964
.120	1.458	2.125	3.099	4.518	6.586	9.602
.140	1.552	2.410	3.741	5.808	9.017	13.998
.170	1.706	2.910	4.964	8.467	14.445	24.641
.205	1.904	3.626	6.904	13.146	25.031	47.663
.235	2.092	4.378	9.160	19.166	40.100	83.902
.400	3.514	12.346	43.376	152.405	535.488	1849.140
.495	4.716	22.425	106.194	502.881	2381.400	....

Values of $\dfrac{e^{fn\pi}+1}{e^{fn\pi}-1}$

$f=$	n = number of half laps on driving drum or drums.					
	1	2	3	4	5	6
.070	9.130	4.623	3.141	2.418	1.999	1.729
.085	7.536	3.833	2.629	2.047	1.714	1.505
.120	5.345	2.777	1.953	1.570	1.358	1.232
.140	4.623	2.418	1.729	1.416	1.249	1.154
.170	3.833	2.047	1.505	1.268	1.149	1.085
.205	3.212	1.762	1.338	1.165	1.083	1.043
.235	2.831	1.592	1.245	1.110	1.051	1.024
.400	1.795	1.176	1.047	1.013	1.004	1.001
.495	1.538	1.093	1.019	1.004	1.001	....

A glance at these figures is sufficient to convince one of the importance of keeping the rope dry. When the rope is at rest, the tension is uniform throughout the line, but when running there is a difference in the taut and slack portions equal to the resistance or load stress, knowing which, the values of T and S may be readily computed from the above formulæ and tables.

The increase in tension in the endless rope, compared with the main rope of the tail rope system, where the stress in the rope is equal to the resistance, is about as follows:

$n =$	1	2	3	4	5	6
Increase in tension in endless rope, compared with direct stress.	Per cent. 40	Per cent. 9	Per cent. $2\frac{1}{3}$	Per cent. $\frac{2}{3}$	Per cent. $\frac{1}{5}$	Per cent. $\frac{1}{10}$

These figures are useful in determining the proper size of rope. For instance, if the rope makes two half laps on the driving drum, the strength of the rope should be 9 per cent. greater than a main rope in the tail rope system.

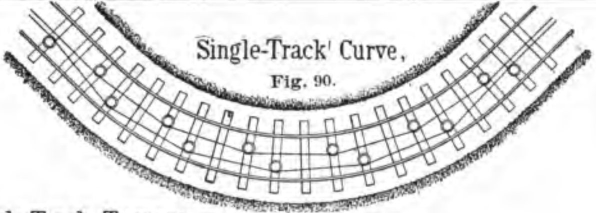
The endless rope system requires a double track, although it is possible to operate it on a single track by providing turnouts at which the in-going and out-going cars may pass, but this arrangement is objectionable since it requires a definite spacing of the cars. Sometimes an endless rope is operated for hauling single trains on a single track, as in the tail rope system, by reversing at each trip and attaching the train to a link socketed in the rope, which presents no objection in this case as it would in the ordinary method of operating where the rope is run continuously in one direction, since the link does not have to pass around the drums.

Connections are made with side entries, as illustrated in Figs. 86 and and 87. The rails must be cut out where the rope crosses, in order to allow the grips to pass, the gaps so formed usually being filled by short bars or pieces of rail pivoted at one end, which are opened and closed by the train riders. An automatic rope-crossing is illustrated in Fig. 88, and consists of a cast-iron plate, *B*, firmly bolted to the ties, with a groove, *g*, through which the rope runs. The latch, *l*, pivoted at *p*, has a beveled end, abutting with the rail end, which is also beveled to fit. This latch completes the rail line, and is set so that it offers no resistance to the passage of the grips. The latch is provided with a spring, *s*, which closes it after a grip has passed, and therefore requires no attention. On single-track lines two of these are placed end to end, as shown in Fig. 87.

Fig. 89 illustrates the arrangement of a turnout in a single-rope line, rope-crossings such as we have just described being required at each of the points marked *B*. Fig. 90 shows the manner of leading the rope

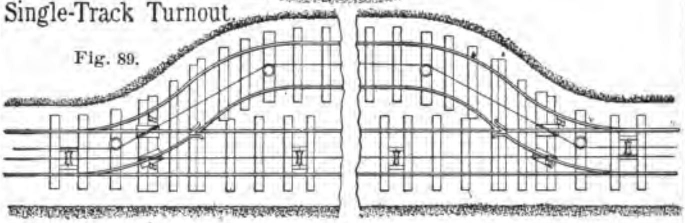
Single-Track Curve,

Fig. 90.



Single-Track Turnout,

Fig. 89.



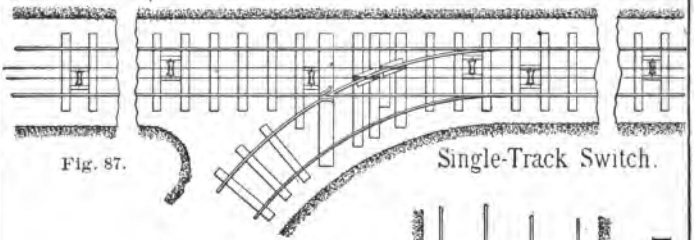
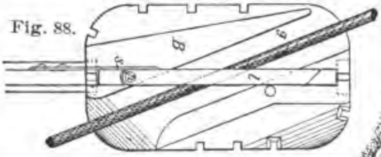


Fig. 87.

Single-Track Switch.

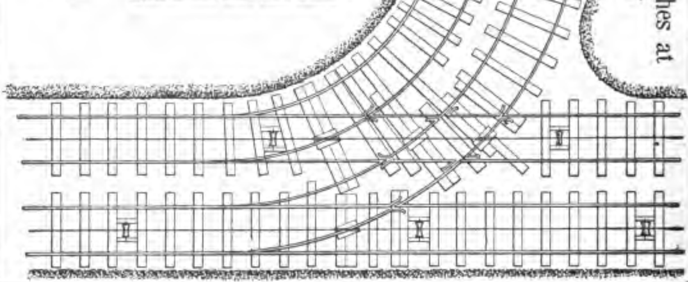
Self-Acting Latch Rail

Fig. 88.



Double-Track Switches at Side Entry

Fig. 86.



around a curve. An arrangement by means of which a side entry may be worked by the rope line is illustrated in Fig. 92. The rope passes around a series of curve rollers between the rails of the in-going track leading into the branch, and in returning is deflected about a sheave, as shown below the in-going track on the main entry, and continues on down this entry. The in-going trains not intended for the branch must be detached at this point.

The illustration on page 23 represents the arrangement of an endless rope line at the East Fork Mine of the Tennessee Coal, Iron and Railroad Company, at Tracy City, Tenn. The line traverses a main tunnel through the mountain, 6,000 feet long, to No. 10 mine, and a branch tunnel, 1,800 feet long, to No. 11 mine, making in all 7,800 feet, as exhibited in Fig. 93. The loaded track at the entrance is on a one per cent. grade, descending to the tipple, while the empty track, after passing over a slight knuckle, is on a one per cent. grade, descending from the tipple for a distance of 250 feet, then level for about 50 feet, then on a three per cent. rising grade until it reaches the level of the loaded track. The loaded cars from No. 10 mine and the empties to No. 11 mine run by gravity across the places where the rope is lacking at the junction of the main and branch lines.

The rope is ¾″ diameter steel, 7-wire, Lang-lay, and travels at a speed of 4 miles an hour. The rope is greased continuously with a mixture of coal tar, car oil and axle grease. The tension sheave, near the entrance, is 5 feet diameter, and is mounted on a carriage, actuated by weights suspended in a gallows frame. The sheave is slightly inclined to the vertical in order that the rope may run on and off properly. The tail sheaves are 6 feet diameter, and mounted on "take-up" slides. The engine is located directly in front of the mine entrance; it has double cylinders, 16x20, and is geared 1:4 to the back drum. This drum is 6 feet diameter, and the forward drum 5 feet diameter. The loaded rope leads direct to the upper side of the back drum, makes three half laps about this and the forward drum, one half lap next about the tension sheave, one half lap finally about a sheave which revolves freely on the driving drum shaft, and leads out under the tension carriage around

Method of Working Endless Rope on Side Entry.

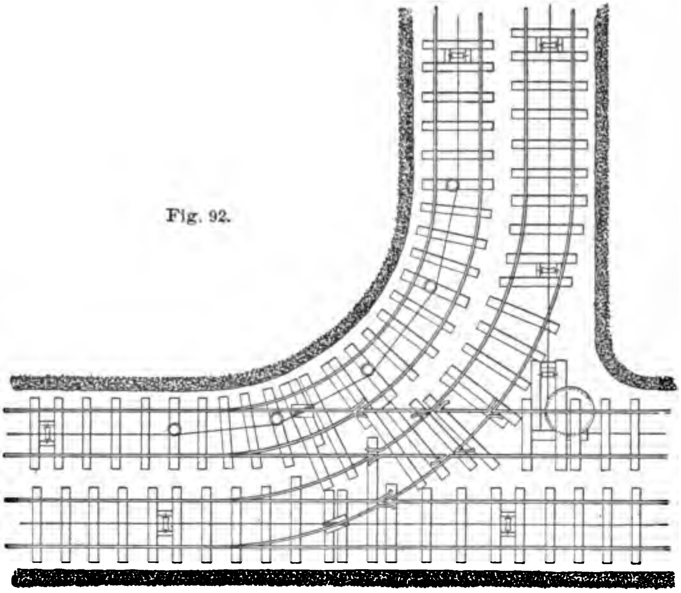


Fig. 92.

Endless Rope Tail Sheave.

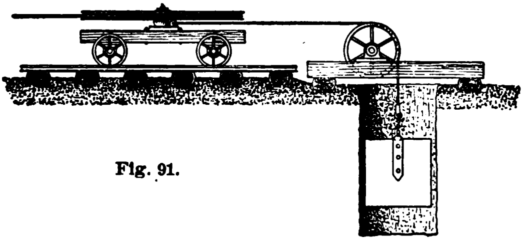


Fig. 91.

Endless Rope Line. East Fork Mine, Tracy City, Tenn.

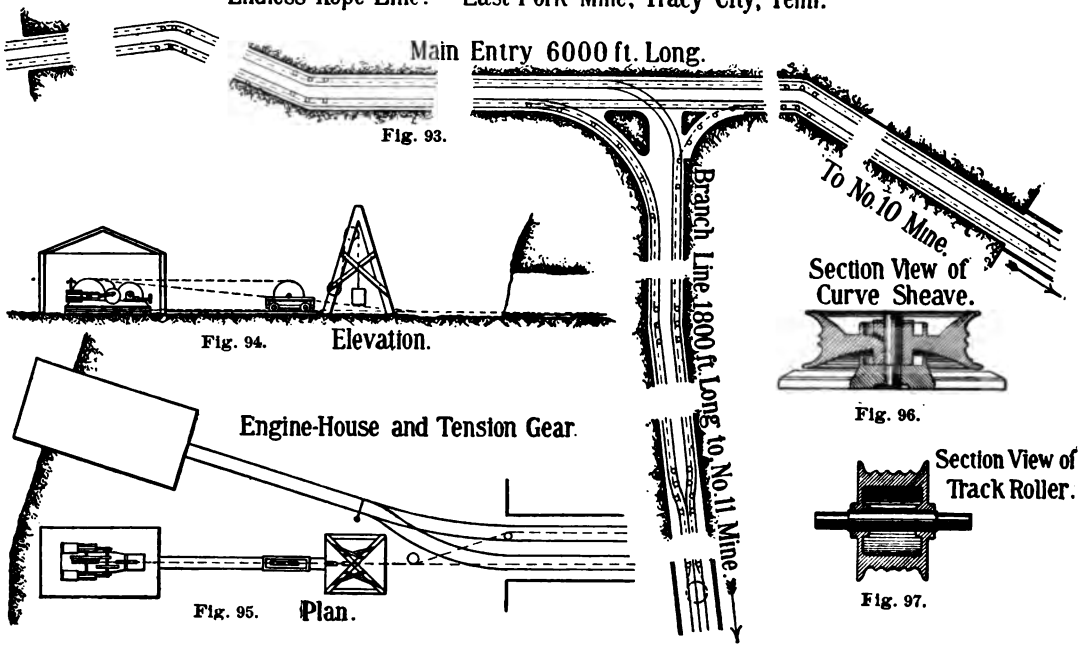

Main Entry 6000 ft. Long.
To No. 10 Mine.
Branch Line 1800 ft. Long to No. 11 Mine.
Elevation.
Engine-House and Tension Gear.
Plan.
Section View of Curve Sheave.
Section View of Track Roller.

Fig. 93.

Fig. 94.

Fig. 95.

Fig. 96.

Fig. 97.

some small guide sheaves to the left. Twenty cars make up a trip, holding each about 1,500 lbs. of coal, and weighing, empty, about 750 lbs. The road is comparatively level, the steepest grade being less than $2\frac{1}{2}$ per cent., and the maximum daily capacity of the line is 1,200 tons. The average cost of hauling for three years, during which the output amounted to some 580,000 tons of coal, was $7\frac{14}{100}$ cents per ton, which includes, besides the rope haulage, the cost of delivery from face of entries at the two mines to the rope terminals by mules, this additional distance varying from a quarter to one mile. The cost of hauling from the rope terminals to the tipple is about 4 cents a ton or 3 cents a ton per mile; this figure including depreciation of plant, etc.

An endless rope line is also used at Tracy City for charging two double lines of coke ovens, known as the East Fork and Lone Rock batteries, and covering a total length of 3,700 feet, in which there are several bends. Two double discharge larries, each of 10 tons capacity, are employed, one for each battery, which travel upon single tracks between the two lines of ovens, and are attached to the endless moving ropes by means of grips. The rope is $\frac{5}{8}''$ diameter, 7-wire, Lang-lay, and runs along the center of the tracks back and forth in double lines over iron rollers spaced from 15 to 20 feet apart, similar to those shown in Fig. 97. The grade on the East Fork battery is $\frac{9}{10}$ per cent. in favor of the loaded larry, and on the Lone Rock battery it is level. An engine of 10 horse-power operates the plant.

An adaptation of the endless rope system is employed in several English mines, in which the rope, instead of being supported on rollers close to the ground, travels above the cars, the attachments being made in a variety of ways. In some cases the rope simply rests in grips on the cars, and supporting rollers are dispensed with altogether. None of these methods have met with much favor in this country, principally on account of the awkward rope connections and cumbersome arrangements necessary at the curves. Where the grades are all in one direction, but a single connection is required, but where they are undulating, connections must be made at each end of the train.

The endless rope system is sometimes applied to the operation of inclined planes, where the inclination is comparatively light and duty very heavy. There are a number of planes of this character in the anthracite region of Pennsylvania, among which may be mentioned the planes of the Central Railroad Company of New Jersey, at Ashley, Pa., and the plane of the Philadelphia and Reading Railroad Company, at Mahanoy. Whole trains of loaded cars, as used on the above railroads, are handled on these planes, the raising and lowering being done by means of "barney" cars attached to the ropes, which run on a track within the main track and drop into pits at the lower ends of the planes leaving the main track unobstructed.

At Ashley there are three inclines, one above the other, with a combined length of 13,020 feet, and total vertical elevation of 1,066 feet. Over 24,000 tons have been taken up these planes in 24 hours, the ropes used being 2½ and 2¾ inches in diameter.

The Mahanoy plane is 2,466 feet in length, with a vertical elevation of 353 feet, and maximum capacity of 1,000 cars in 24 hours, or about 25,000 tons. A 2½-inch rope is used.

COMPARATIVE ADVANTAGES OF THE TAIL ROPE AND ENDLESS ROPE SYSTEMS.

As to which is the better of the two systems of haulage is a matter that depends largely on the local conditions. The tail rope system possesses the decided advantage that crookedness of the line, irregularity of gradient and numerous branches, offer no obstacle to its effective working. To obtain a large output, however, the ropes must be run at high speeds, and as the workings become more extended, an increased number of cars must be hauled, which adds to the stress on the engine and rope, and the wear and tear therefore is heavier than with the endless rope system, where the rope is run at a moderate speed, and the load more uniformly distributed. The endless rope system requires one-third less rope than the tail rope system, but this advantage is offset by the fact that the rope must be of uniform diameter throughout, and of a size corresponding to the greatest tension under which it will be worked. The power required

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to operate is less than with the tail rope system, since the rope travels in most cases at less than half the speed, and the friction of an unwinding drum and unloaded rope is not added to the weight of the trips. This fact, in addition to the less quantity of rope required on a line without branches, makes the first cost of the plant somewhat less. The greatest objection to the endless rope system appears to be the difficulty encountered in working branches. These may be operated by independent lines, and conditions may occur where this method of working might be employed to advantage, but in most cases where the length of main line is no drawback, the tail rope system is to be recommended in working lines with branches. Another objection to the endless rope system is the undue stress on the rope produced by the unequal wear of the grooves in the drums, to say nothing of the great stress on the shaft and bearings, which amounts to the sum of the stresses in all the parts or folds of the rope. The undue stress in the rope may be obviated in a measure by using in place of the forward drum, independent sheaves corresponding in number to the folds of the rope, and one of which is keyed to the shaft, but this can only be done when the back drum alone is the driver. The best thing for this purpose is the so-called differential drum devised and patented by Mr. John Walker, of Cleveland, Ohio. The grooved surfaces, instead of forming an integral part of the rim of the drum, are turned in a number of independent steel rings, confined loosely between the flanges of the rim, as shown in Fig. 98, there being as many of these rings as there are grooves required. The surface of contact between the rings and the rim must be such that the frictional adhesion is less than that between the rope and the rings, but still sufficient to transmit the desired amount of power, which is effected by lubrication. When any difference occurs in the groove diameters of the rings, due to unequal wear, the rings will adjust

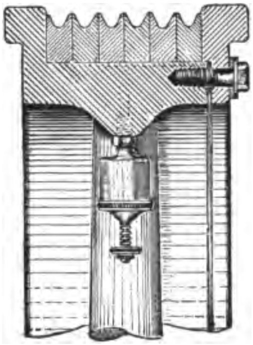


Fig. 98.
Rim Section of Walker Patent Differential Drum.

themselves, or compensate for such differences, by slipping sufficiently to maintain the normal tensions in the different parts of the rope, due to grooves of equal diameters. In other words, the slip, instead of occurring between the rope and the grooved surfaces of the rings, is transferred to the flat surfaces, between the rings and the rim of the drum, where the wear is distributed over a greater area, and is consequently less rapid, and as the rings become worn with use they can be readily renewed.

The extensive application of both the tail rope and endless rope systems to surface as well as underground lines has demonstrated beyond all question the economy of wire rope haulage, and this economy is very marked where the grades are unfavorable to the load. The cost of wire rope haulage, by either the tail rope or endless rope systems is about the same, and varies, according to the grades, from 2 to 3 cents a ton per mile, which is less than one-third that of mule haulage. The above cost is distributed in percentages about as follows:

System.	Rope.	Maintenance.	Power.	Labor.
Tail rope........................	15	24	30	31
Endless rope....................	13	26	12	49

The main difference in the above comparison appears in the items of power and labor. While the endless rope system is more economical of power, it is more costly for the labor in handling the cars, and this fact should be taken into consideration in the selection of either system.

Hoists.

UNDER the caption, "Hoists," will be considered vertical or steep inclined passageways through which materials are raised or lowered in cages or skips.

Hoists through which the material is raised vertically comprise the ordinary forms of elevators, lifts, or shafts, so familiar to most people, that few words will suffice on this subject. The usual arrangement is for two cages, which balance each other, and are operated by a reversing engine with two drums at the shaft-head, one cage ascending while the other descends. Where a single cage is used, balance weights are provided for relieving the engine of the duty of having to lift the dead weight of the cage. The ropes are led from the drums over head-sheaves varying according to the load and size of rope up to 18 feet in diameter, and are attached by means of sockets to the cages supporting the cars.

Fig. 99 illustrates a common form of cage used in the coal regions. The guide bars on the posts between which the cage works are usually of wood, and in order to guard against accidents in case of the rope breaking, the cage is provided with safety catches, the action of which is such that the instant the tension is released, as it would be in case of a break, the toothed cams shown at the side of the cage imbed themselves in the guide bars, and thus arrest the descent of the cage.

The cages should always be equipped with "safety hooks." In case "overwinding" should occur, due to carelessness of the engineer or accident, these hooks simply detach themselves from the rope, leaving the cage suspended in the upper guides, while the loose rope-end merely winds around the drum, thus avoiding the wrecking of the cage and destruction of the whole head-gear of the shaft. A good hook of this kind is illustrated in Fig. 100.

The engine drums are either plain or grooved iron cylinders, or iron rims, lagged with wood, the relative merits of each depending on the conditions under which they are operated. In many mines, especially where the shaft is of considerable depth, the engine drums are made conical. The ropes are attached to the small ends of the drums, the one winding while the other unwinds. These are called "fusee" drums, and

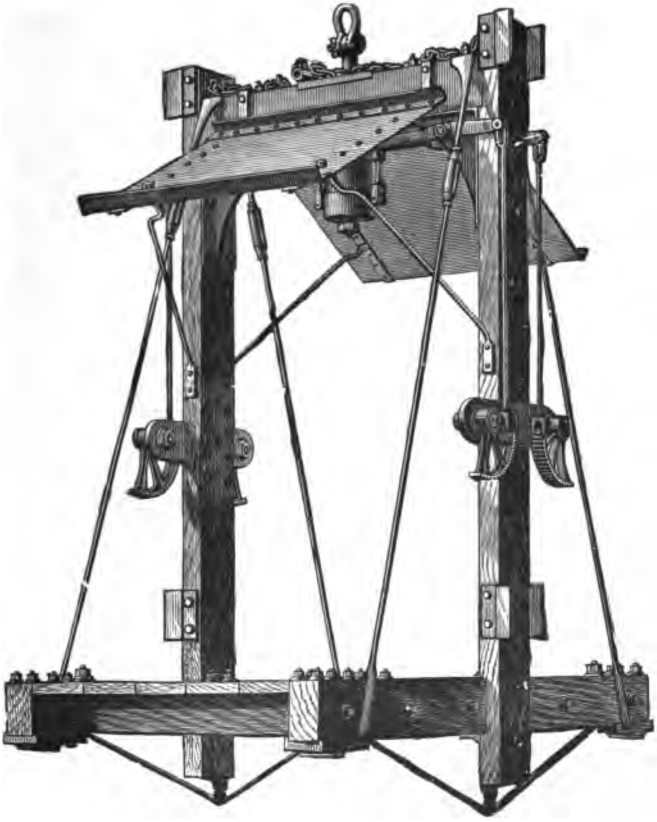


Fig. 99. Elevator Cage.

possess the advantage of a diminishing leverage in hoisting opposed to an increasing leverage in lowering, so that the effort in starting is gentle, and the work done by the engine more uniform. The same advantage pertains in a greater degree to the use of flat ropes, which are coiled on reels, and which possess the further advantage of always working in the same direct lines, giving steadier motion to the cages. In many very deep shafts, where rapid hoisting is desirable, these ropes are preferred on this account. It is advisable, however, with flat rope, to use a larger factor of safety than with the round rope of equal strength, the proportion between their weight for equivalent working strength being about as 7 to 5 in favor of round rope.

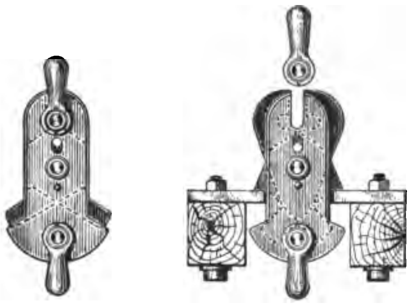


Fig. 100.

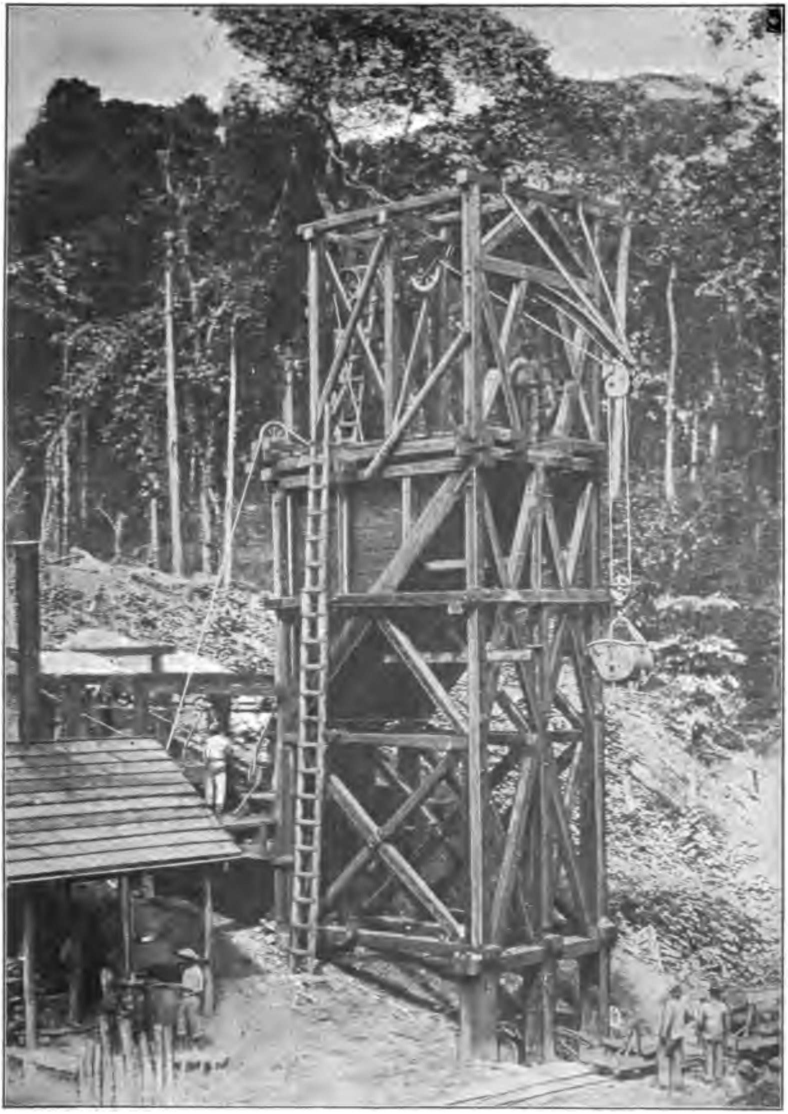
Humble's Patent Safety Detaching Hook.

The engine drums are sometimes driven from the engine shaft through a pinion and gear-wheel, although in most mines direct-acting engines are now used, or engines in which the connecting rods are coupled direct to the drum shaft.

Where it is desired to deliver the coal or ore at the shaft-head without further handling, an automatic-dumping cage, such as shown in Figs. 101 and 102, is used. By this arrangement the material is dumped on to the screens or chutes, as the case may be, without the car leaving the cage. The cage is shown at the point just about to tilt, the position in the act of tilting being indicated by the dotted lines.

SKIP HOISTS.

Where the shaft is a very steep incline, the materials are hoisted in peculiar-shaped cars called skips (shown in Figs. 103 and 104), and such

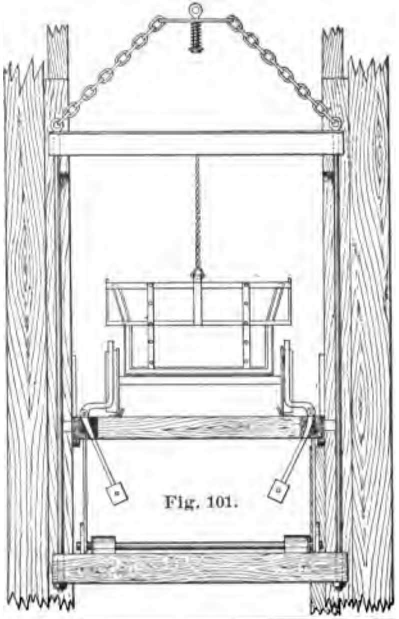


HOIST,

Built by THE TRENTON IRON CO.; Trenton, N. J.,

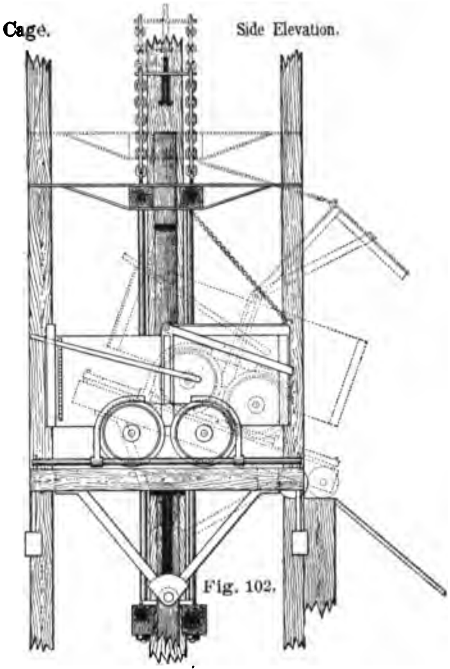
For The Caribbean Manganese Co., Colon, Colombia, S. A.

Self-Dumping Elevator Cage.



Front Elevation.

Fig. 101.



Side Elevation.

Fig. 102.

Skip Hoists.

Fig. 103.

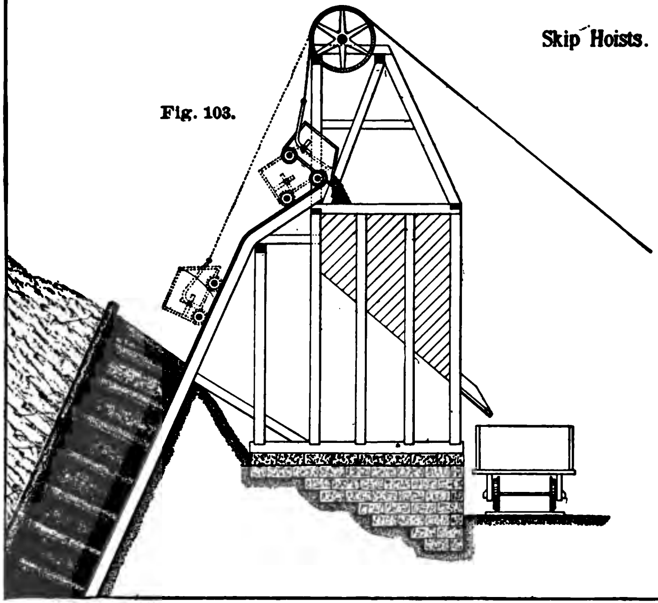
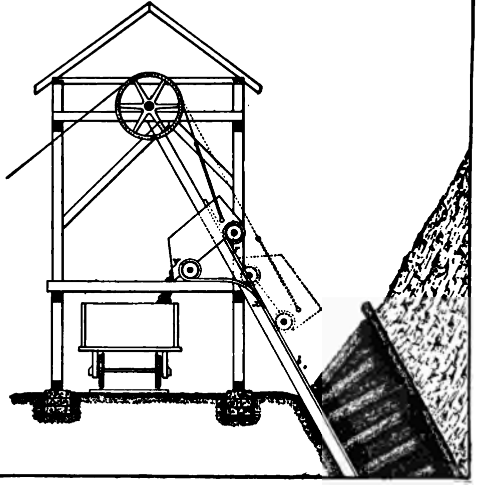


Fig. 104.



shafts are commonly known as skip hoists. At some mines these cars are called "gunboats," and are made to hold from 3 to 5 tons. Fig. 103 illustrates the arrangement at one of the mines of the Lehigh Zinc and Iron Co. The skip is provided with a bail composed of two side bars curved at their lower ends, and hinged to the sides of the skip near the lower corners. The upper ends of these bars are connected by a square bar with round ends, to which the chain at the end of the rope is attached. The rope passes over a head-sheave at the top of the framework, to the engine. For a short space at the shaft-head the track bends down to a lighter inclination, and the ends of the rails are turned up to fit the wheels of the skip. When the front wheels reach these turned-up ends, the engineer is signalled to hoist slowly, lifting the back end of the skip off the track sufficiently to discharge the load into the bins or cars. The engine is then reversed and the skip runs back into the mine.

Another arrangement is illustrated in Fig. 104, the skip being constructed with one set of narrow-tread wheels in front and a set of double width of tread in the rear. When the skip arrives at the shaft-head, the front wheels run on to the bent portion of the track *b*, extending from *x* to *y*, passing between the rails, *r*, of wider gauge at the upper end, while the rear wheels, on account of their broad tread, take the rails, *r*, and continue on to the proper height for tipping and dumping the load.

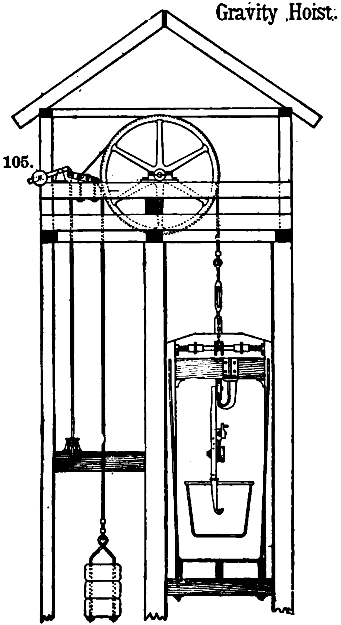
GRAVITY HOISTS.

When the load is a descending one, gravity may become the motive power, and the cages operated by means of brakes applied to the head sheaves. An arrangement of this kind, illustrated in Figs. 105 and 106 is used by the Solvay Process Company, of Syracuse, to deliver limestone from the upper benches of a quarry to the loading bins of a Bleichert wire rope tramway.

The head-sheaves are fitted with brakes, and provided with oval-faced rims, as shown in Fig. 107. The rope in each compartment is given three laps about the sheave, which is sufficient to prevent slipping. Counterweights are provided, as shown, which are heavy enough to lift the cage

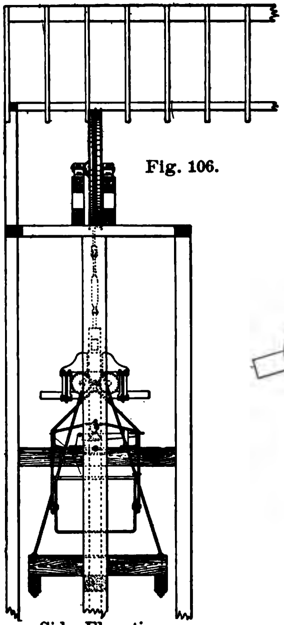
Gravity Hoist.

Fig. 105.



Front Elevation.

Fig. 106.



Side Elevation

Rim of Head Sheave

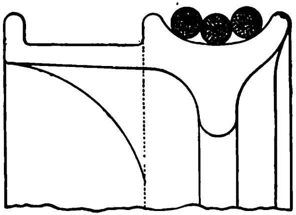
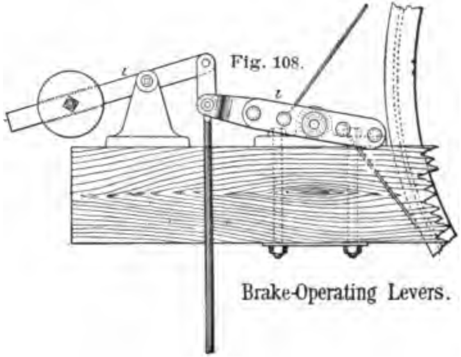


Fig. 107.

Fig. 108.



Brake-Operating Levers.

with the empty car, and light enough to be lifted by the cage containing a loaded car. The arrangement of the brake-operating levers is shown in Fig. 108. The rod, *r*, attached to the levers, *l* and *l*, extends to the bottom of the shaft, and by means of this the cages are stopped or started from any level.

Inclined Planes.

WE HAVE to consider under the caption "Inclined Planes," the various methods of operating wire ropes on slopes of varying inclinations, the range of which seems to have no well defined limits. The term "Inclined Plane" has been applied in the anthracite coal regions of Pennsylvania to a class of lines operated by endless ropes on slopes of comparatively light inclination, and used for raising and lowering whole trains of coal cars, which have already been referred to as endless rope lines (see page 25). We shall consider as inclined planes, lines not so steep as to require cars of special design like skip hoists, nor so shallow that the cars will not descend the slope freely by gravity. There are two kinds of such inclined planes; one in which power is required to raise the loaded cars, designated as Power Planes, and the other, Gravity Planes, in which the loaded cars descend by the gravity of their own weight.

POWER PLANES.

Power planes may be operated either on single or double tracks; a single or double-drum hoisting engine being required as the case may be. Non-reversing engines are usually employed, the drums being driven through friction clutches, and fitted to control the descent of the empty cars. The slopes are often of considerable length, with curves and varying grades. When the grade at the upper end is too slight to start the empty cars by gravity, or where the tipple is located some distance back from the head of the slope, on a level track, mechanical means may be resorted to for starting the empty train, as illustrated in Figs. 109 to 112, showing the arrangement employed on a slope at Blocton, Ala. A heavy

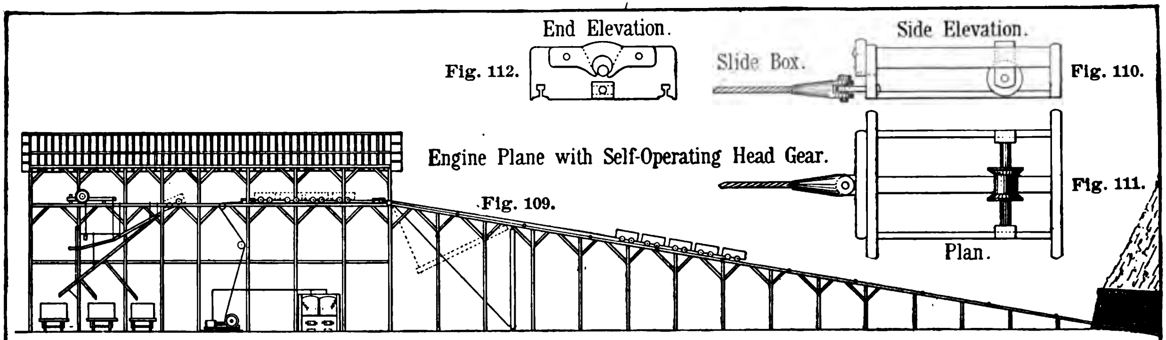


Fig. 112.

Fig. 110.

Engine Plane with Self-Operating Head Gear.

Fig. 111.

Fig. 109.

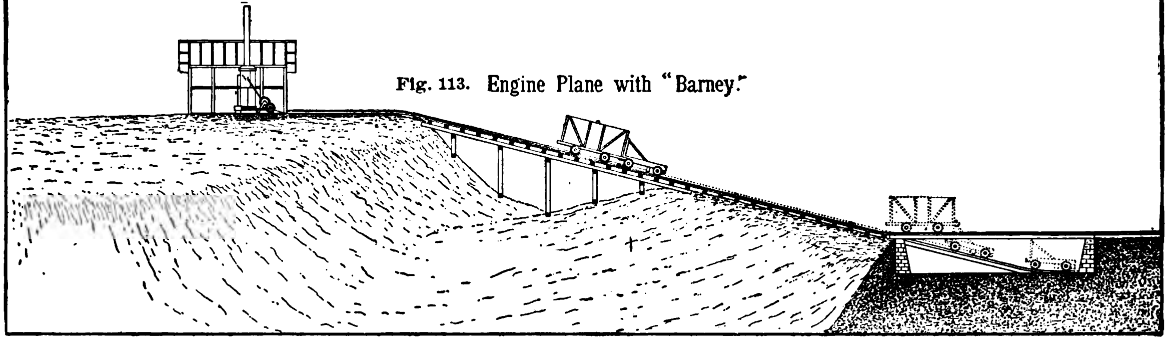


Fig. 113. Engine Plane with "Barney."

wooden beam suspended below the trestle is raised by the loaded cars as the train is drawn into the tipple, to the position indicated by the dotted lines, and is held in this position until the empty train is made up, when the brake on the engine drum is released, and the beam falls, pulling the empty train with it on to the slope. If it is not practicable to use a suspended beam in the manner shown, a counterweight working in a pit or gallows frame will serve the same purpose.

Power planes are frequently operated as shown in Fig. 113, the raising and lowering of the cars being effected by means of a smaller car known as the "barney," which is permanently attached to the end of the rope. The barney travels on a narrow track within the main track and drops into a pit at the foot of the slope out of the way. By this method of working there is no time lost as in the ordinary method in the coupling and uncoupling of the cars to the rope.

A power plane may be adapted to work a series of side entries in a mine, as illustrated in Fig. 114. Each side entry has a parting at its junction with the main gangway for the accommodation of the trips in going in and coming out of the different entries, the empty cars being delivered to the various partings in succession, and the loaded cars, standing on the opposite track, taken out. A horizontal sheave is placed at each bend within a few inches of the track, around which the rope runs. By means of marks on the rope, or an indicator, the engineer is enabled to stop the "empties" alternately at the different junctions. A man passing from one junction to the other attends to the switches, attaches and detaches the rope, and gives the proper signals to the engineer.

Under ordinary conditions the minimum grade for an engine plane is about 3 per cent. On lighter grades than this the empty cars will not descend freely. While it requires a fall of at least 3 per cent. for empty cars to descend freely, loaded cars will descend much lighter grades. A train of twenty-five to thirty mine cars, for instance, holding a ton each, will descend a grade of 1¾ per cent., and in such cases where the grade is insufficient for the gravity of the loaded cars to pull back the empties, power must be employed for this purpose. Inclined planes of this kind are frequently adapted to the feeding of long lines of coke ovens, which

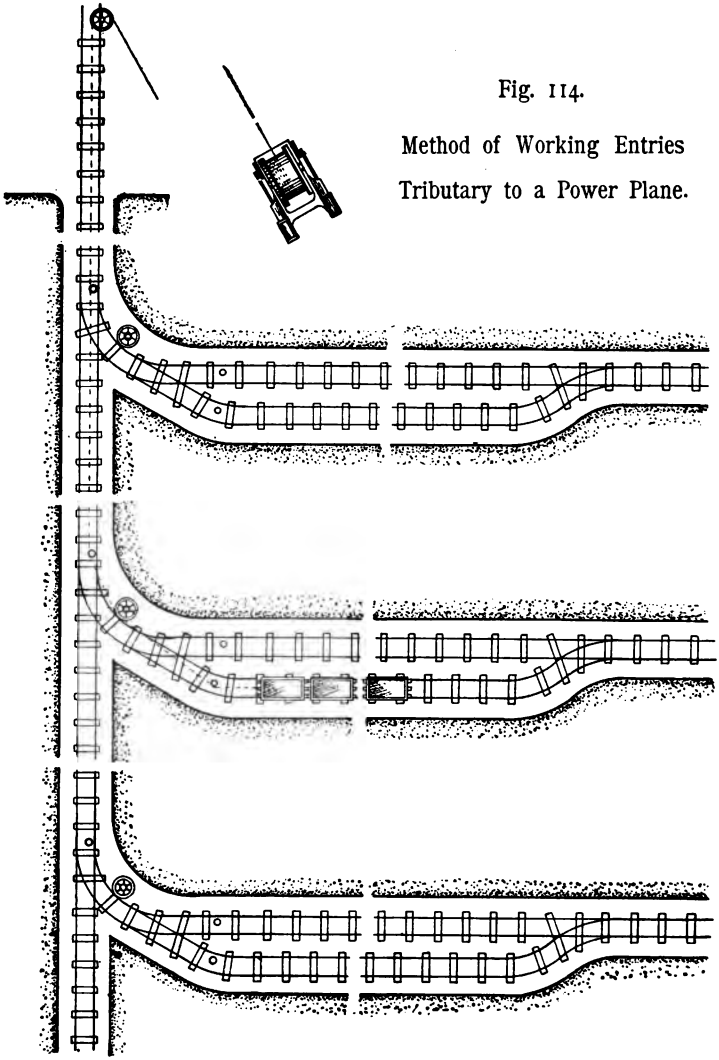


Fig. 114.

Method of Working Entries Tributary to a Power Plane.

are built on an inclination just sufficient for the loaded larry to descend easily, and power used to haul the empty larry back. A line of ovens at Blossburg, Ala., is fed in this way, the inclination of the tracks being 1:35, or a grade of about 3 per cent.

GRAVITY PLANES.

The ordinary arrangement of gravity planes is illustrated in Figs. 115 and 116, and consists of a drum at the head of the slope, located preferably below the tracks, as shown. Where space will not permit of this arrangement, the drum may be mounted in a frame above the tracks. The drum revolves on a horizontal axle, and the two ropes attached respectively to the loaded and empty cars coil and uncoil on it alternately. The construction of the drum varies according to the requirements; they are sometimes entirely of iron, but more generally lagged with wood, as shown in Fig. 117, being provided with a rim for the brake band to work in. For the convenience of the operator in watching the cars, the brake levers are preferably placed near the top of the slope. Instead of one large drum, two small ones keyed to the same shaft (Fig. 118) may be used. In either case one rope leads from the top and the other from the under side of the drum. Where this is an objectionable feature, the arrangement shown in Fig. 119 may be used, which allows of both ropes leading from the top. The two drums in this case are on different shafts, connected by a pair of spur gears, and consequently revolve in opposite directions. In using double drums it is sometimes necessary to provide for the unequal stretching of the two ropes, and this is very easily effected by the special arrangement of spiders shown in Fig. 120. The end spiders of the drums are secured by means of pins, *p*, *p*, to a central spider, *s*, keyed to the shaft, and by changing the relative positions of these spiders any desired adjustment may be made. This style of drum is also applicable to engine planes where it is desirable to work from different levels.

The arrangement illustrated in Figs. 123 and 124 is designed for slopes too long to be operated in the way just described, on account of

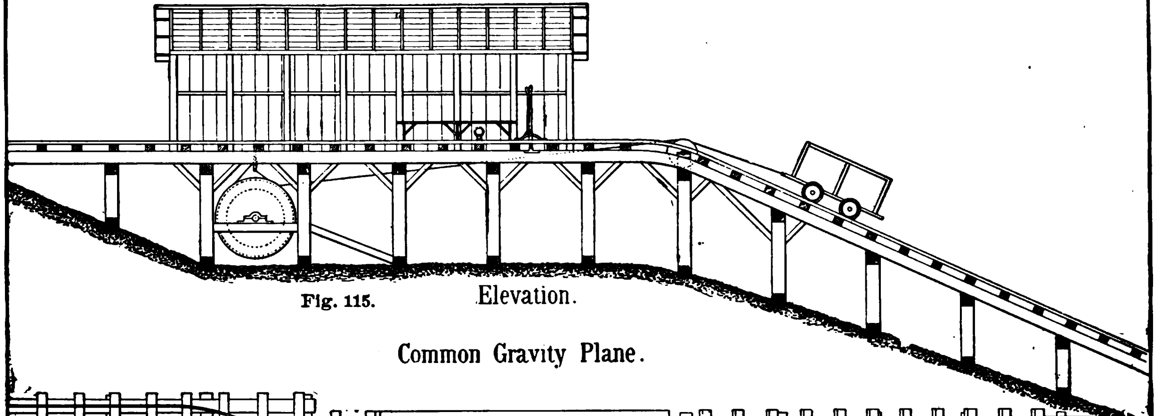


Fig. 115. Elevation.

Common Gravity Plane.

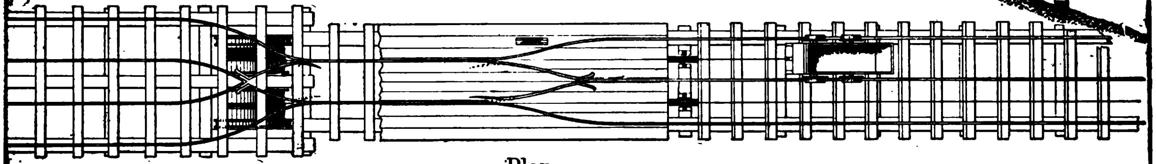


Fig. 116. Plan.

Fig. 120. Compensating Spider.

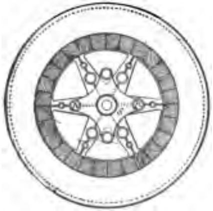


Fig. 122. Automatic Terminal Switch

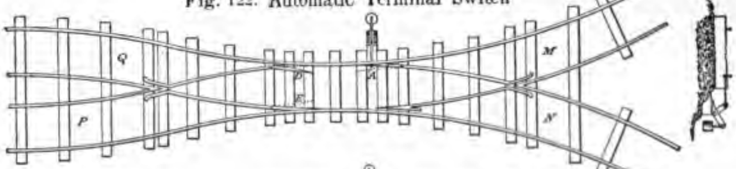
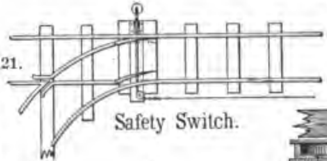


Fig. 121.



Safety Switch.

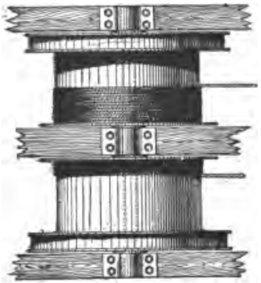


Fig. 118.

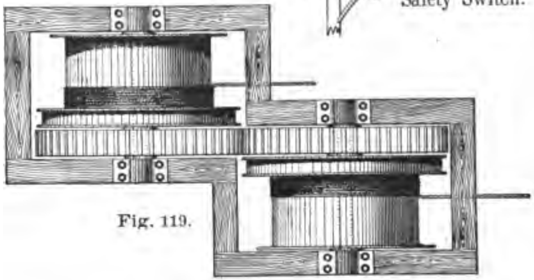


Fig. 119.

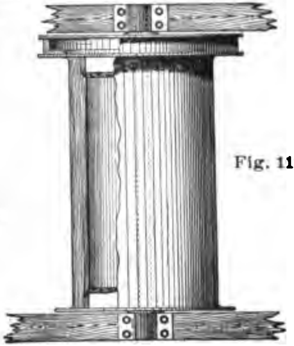


Fig. 117.

Various Styles of Head Drums.

Gravity Plane.

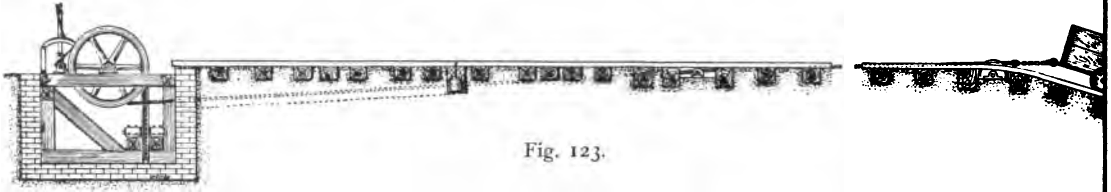


Fig. 123.

Arrangement of Head Sheaves for Long Slopes.

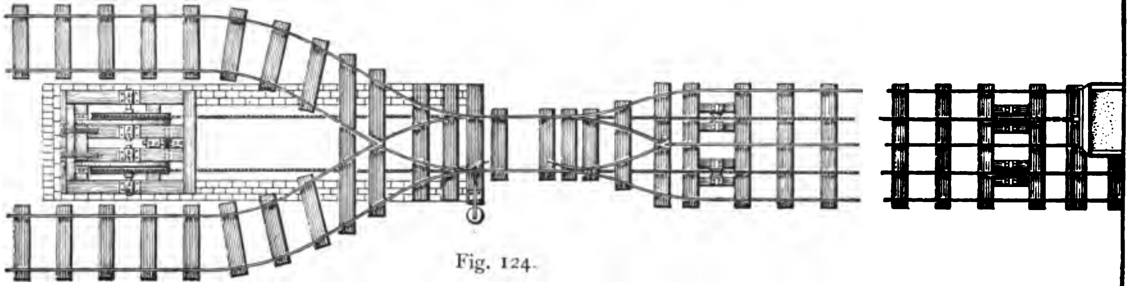


Fig. 124.

requiring drums of inordinate dimensions to hold the necessary amount of rope, and is also well adapted to shorter slopes, provided the difference in the tensions of either branch of the rope, due to the weights of the loaded and empty cars, is not so great as to cause it to slip on the sheaves. There are three vertical head sheaves, two with filled rims mounted in planes parallel and coincident with the two branches of the rope, and one below these of a diameter equal to the gauge of the track center lines, in a plane at right angles to the rope and tangent to the circumferences of the upper two at the forward side. The upper sheaves are fitted with the necessary brakes, operated by levers, as shown, and mounted so that the axles are about on a level with the rails. At a point back from the head of the slope, a distance equal to or something greater than the length of the train of cars, the rope which is in one piece, passes over rollers below the tracks to the sheaves, making three-quarters of a lap on each of the upper two, and one half a lap on the other, so that it runs off one side and on the other.

The different ways of laying the tracks for gravity planes are illustrated on the following page. Fig. 125 represents a regular double-track line on which the loaded cars descending on one track pull up the empty cars on the other. This is, of course, the safest, though most expensive arrangement. A cheaper arrangement, and one which answers the purpose quite as well, is shown in Fig. 126, and consists of a three-rail track, having a "parting" or double track at the middle of the incline, long enough to allow the descending and ascending cars to pass each other. A still cheaper arrangement is that shown in Fig. 127; a three-rail track extending from the slope only to the central parting, and a single track below that. A self-acting switch at the lower end of the parting serves to guide the cars alternately from one to the other side of the upper track. Fig. 129 shows a common arrangement of this switch, and, as shown in the cut, an empty car going up will take the track, *s*, and the loaded car coming down the track, *m*, will shift the timbers to the position indicated by the dotted lines. At the next trip the empty car will run on the track, *m*, and the loaded car, this time descending on the track, *s*, will shift the timbers again to their original position,

Fig. 128.

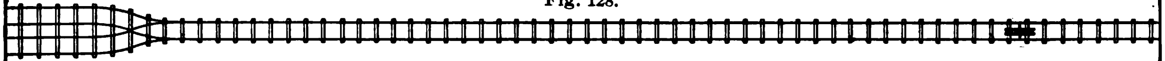


Fig. 127.

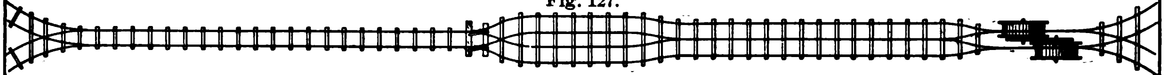


Fig. 126.

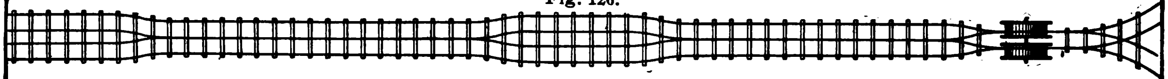
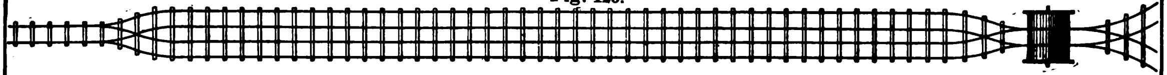


Fig. 125.



Various Arrangements of Tracks.

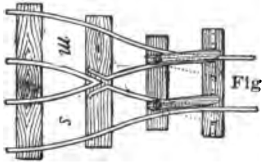
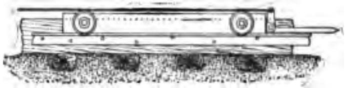


Fig. 129.

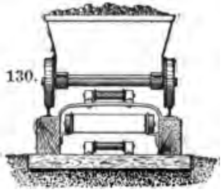
Automatic Switch.

Fig. 131.



Bob Plane. Balance Car.

Fig. 130.



Bob Plane.
End View of Car.

the same play being repeated at each round trip. This switch is effective, and accidents with it are of rare occurrence. In cases where difficulties occur to prevent obtaining sufficient width to permit the passing of two cars, automatic gravity planes, worked with a counterweight and generally known as "bob planes," can be used; such an arrangement is illustrated in Fig. 130, and consists of a double track, one inside the other; the outer for the mine cars, and the inner, of lighter rails or angles, for the balance car (Fig. 131). The latter is constructed in the shape of a shallow iron box, on wheels, heavy enough to pull an empty car up the plane, and light enough to be raised by a descending loaded car. The wire rope is secured to an angular bar behind the balance car, which drops, in case of an accident to the rope, and arrests the car. The head drum may be a grip-wheel, or what is better and cheaper, an oval-faced sheave, around which the rope makes several laps, similar to that described in connection with the gravity hoists (Fig. 107, page 35).

Fig. 122, page 43, represents an arrangement of switches commonly used at the head of gravity planes, and consists of three switches, *A*, *D* and *E*, which automatically govern the disposition of the cars. The switch *A* is actuated by a spring or weight which always keeps it closed. As shown, a loaded car coming from the track *M* opens the switch *A* and passes to the track *Q*, the switch *A* closing immediately after the car passes it. The empty car ascending by the track *P* opens the switch *E* and closes *D*, passing to the track *N*. The next loaded car from the track *M* will pass to the track *P*, the empty car from the track *Q* opening the switch *D*, closing *E*, and passing to the track *N*. The loaded cars thus descend alternately by the tracks *P* and *Q*, and the empty cars always pass to the track *N*.

For long steep slopes and heavy output, requiring ropes of large diameter and powerful brakes, the arrangement illustrated in Figs. 132 and 133, representing the gravity plane head gear of The Pleasant Valley Coal Co., at Castle Gate, Utah, is to be recommended. This consists of seven independent sheaves with wood-filled rims, each 6 feet in diameter, three of which, a, b, c, are mounted horizontally upon one shaft f, two d, e, tilted slightly from a horizontal plane on another shaft g, and two, h, i, tilted

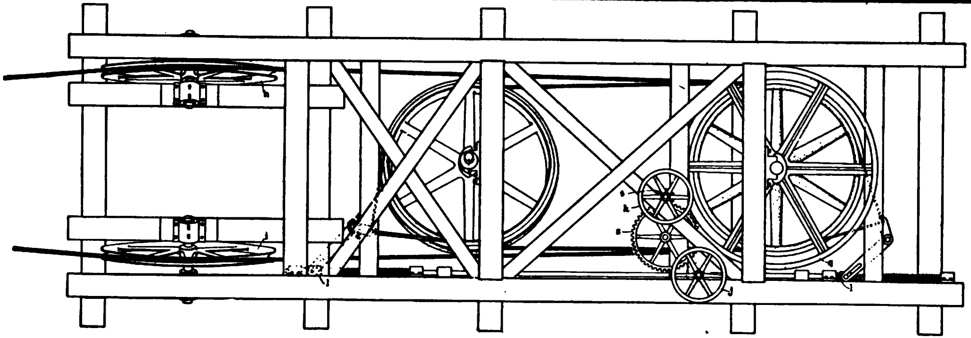


Fig. 132.

Gravity Plane.

Arrangement of Head Sheaves
for Heavy Duty.

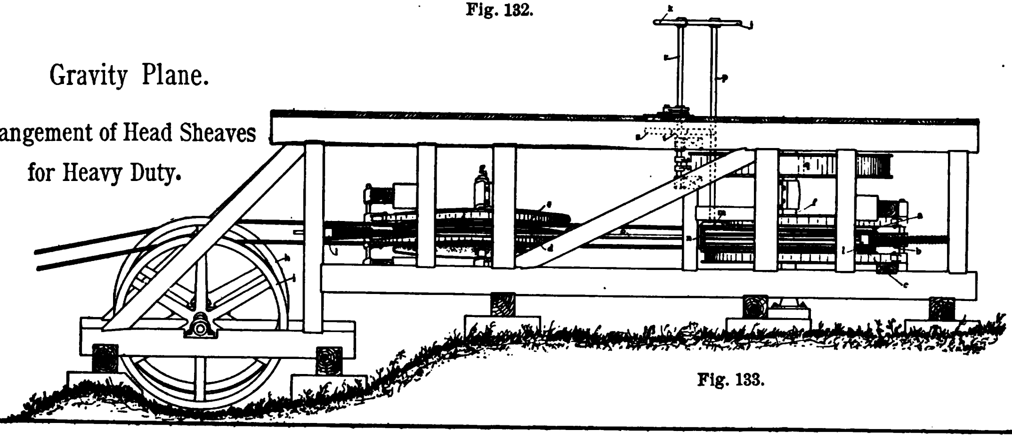


Fig. 133.

slightly from a vertical plane, the latter serving to guide the rope to and from the slope and the horizontal sheaves about which it laps. Of the five horizontally mounted sheaves, the bottom ones, c and d, are keyed to the shafts, and the others are free or loosely mounted. All of these sheaves excepting the middle one, b, which is hidden from view on the shaft f, are provided with brakes having 6-inch wood-lined bands, operated by a band wheel j through a rod p, and bevel gears m and n, and a shaft o with a square-thread screw on each end, that works in sleeves l, l, connected with the wood-lined bands. A band wheel q, 7 feet in diameter with 8-inch face is mounted on the shaft f above the sheaves to provide the necessary braking surface, since it is manifest that the application of a brake band to the middle sheave b would have rendered necessary a separation of the rope parts and tilting of the forward sheaves d and e to an undesirable degree. The band wheel q is also fitted with a wood-lined band, which is operated by the band wheel k, through the rod r and the spur gears s and t. So much of the power therefore as is absorbed by the band wheel q, has to be transmitted through the shaft f. The length of the slope is 1,825 feet, and the fall in this distance 300 feet, developing on an output of 180 tons of coal per hour about 56 horse-power. It is estimated that the cost of operating under favorable conditions, including repairs, will not exceed five-eighths of a cent per ton. This arrangement of sheaves obviates the difficulty with multiple grooved drums heretofore used on such gravity planes, due to the unequal wear of the grooves, which subjects the rope to undue strain, fracturing the outer wires and soon destroying it.

Figs. 134 and 135 illustrate a type of gravity plane used at some iron mines in the vicinity of Birmingham, Ala. The arrangement consists of a platform car on which the mine cars are carried two at a time. This platform car is attached to a rope which makes a half lap on a brake sheave at the head of the plane, from which it leads to a sheave on a balance car, around which it makes a half lap, and extends up the slope to an anchorage near the check house. The balance car, commonly known as the "dummy," travels on a separate track parallel with the main track, the movement being one-half that of the

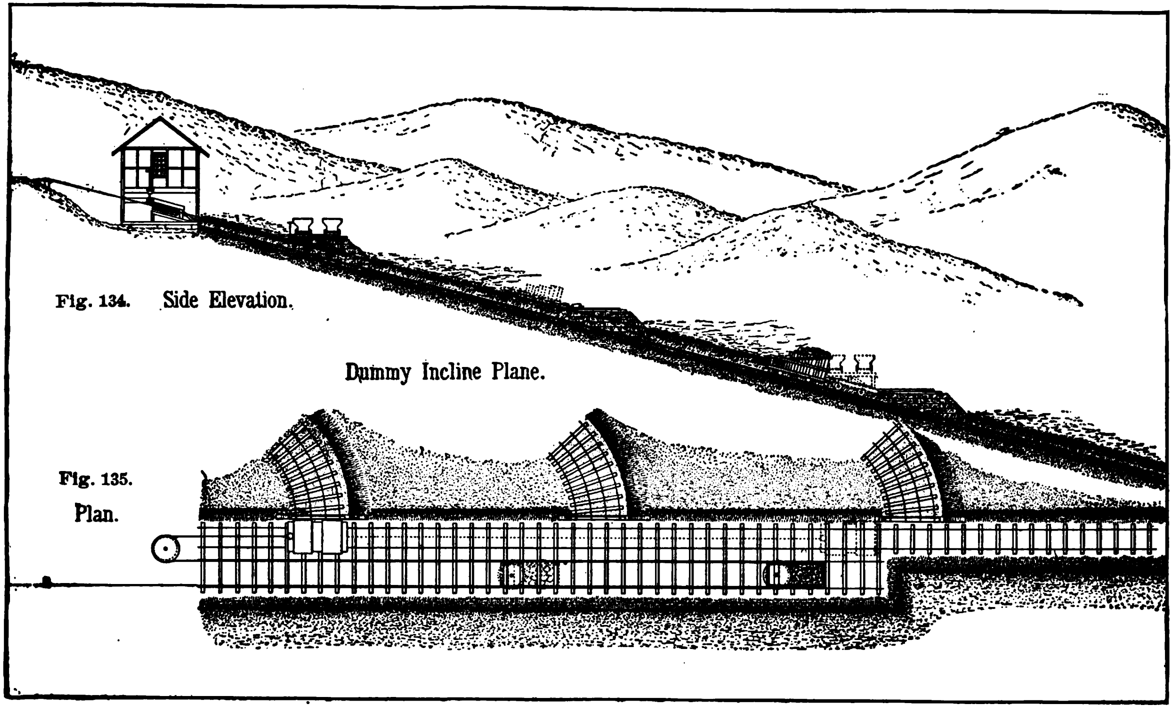


Fig. 134. Side Elevation.

Dummy Incline Plane.

Fig. 135. Plan.

incline car on the main track. The dummy is weighted just sufficiently to lift the incline car, supporting the two empty mine cars on their return to the workings. This style of plane is peculiarly adapted to mines that are worked in terraces, or on a series of "headings," as they are termed, at different levels along the side of a hill. Wooden track rollers are generally used, with a few iron ones interspersed where the wear is heavy. In laying out these planes allowance must be made for the variation in the weight of the ropes on the two tracks. This adjustment may be effected in the profiles of either the main or dummy tracks, or partly in both. It is usually more convenient to make it in the dummy track, as this is but half the length of the other, and independent of the location of the headings. In effecting a landing at any heading, the incline car is brought to a stop or a slow speed, within a few feet of it, by the brakeman on the car, who works the brakes gently, till the rails at the heading abut nicely with those on the car, when the car is stopped. The brakeman at the head of the plane then applies the brake to the head sheave; the empty mine cars are run off and replaced by loaded ones. In the best constructed planes of this class, the tracks at the various headings are so arranged that the transferring of the cars to and from the main slope is done entirely by gravity, either by independent gravity planes such as already described, or by taking off the empties at points above the workings, and taking on the loaded cars at points below, so that there is a fall, in either case, sufficient to operate by gravity. An indicator at the check house marks the location of the incline car on the slope. The objection to this system is the loss of time in effecting landings, and the close adjustment of balance weights required to enable the brakeman on the car to do this. This difficulty may be avoided by tipping the mine cars at each heading and discharging into a box car on the plane, specially designed for the purpose.

Incline cars for gravity planes may be constructed to dump automatically, as shown in Fig. 136. The car is fitted with a pair of wheels in front which have a wider tread than those in the rear. These run on to a short section of track at the foot of the plane, the rails of which are level, or nearly so, and are wide enough apart for the back

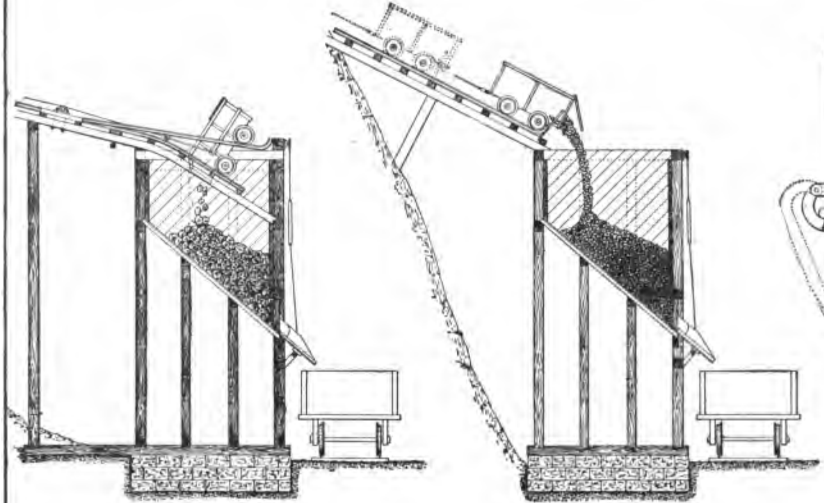


Fig. 136.

Fig. 137.

Self-Dumping Incline Cars.

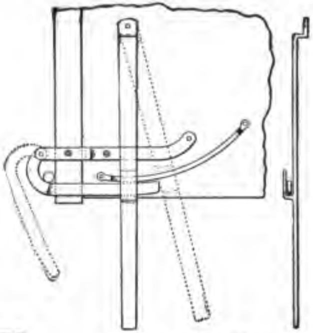


Fig. 138.

Automatic Latch.

wheels to clear, the latter running on to the steep end of the main track, and discharging the contents from the rear end of the car, as shown. The incline car shown in Fig. 137, discharges from the front, the door being secured by an ingenious latch, which opens automatically on reaching the foot of the plane. The construction of this latch is shown in Fig. 138.

The speed of lines operated by gravity with the aid of brakes may be regulated by a very ingenious and reliable hydraulic apparatus which we are prepared to furnish. This is geared to the shaft upon which the sheaves are mounted, and operates in such a way that, when running slowly, it offers little or no resistance, but when the speed exceeds a certain predetermined rate for which the machine is constructed, it exerts a corresponding resistance by which the excess of power developed is absorbed, and a uniform speed thus maintained.

No rule can be given for determining the least inclination for a gravity plane, as this depends on the length of the plane, the number and weight of the loaded and empty cars handled at each trip, the grades, and curves in the road-bed. For planes up to 500 feet in length the minimum grade is about 5 per cent. For longer planes, up to 2,000 feet, it varies from 5 to 10 per cent., being greater in proportion to the length of the line and less in proportion to the load.

The ideal slope for a gravity plane is one approximating a cycloidal curve in profile with the steepest inclination at the top, as the starting effort due to the loaded cars in this case is a maximum one and the finishing effort a minimum one, the converse conditions applying to the starting and finishing resistances due to the empty cars. The curve also is one corresponding with the least time of descent for a falling body on a slope. It goes without saying therefore that slopes with shallow grades at the top and steep ones at the bottom are not well adapted to the operation of gravity planes.

Frequently two or more slopes are operated by a system of inclined planes, which may all dip the same way or in different directions, and may be either self-acting, or require power, according to the grades. The best method of working in any case will depend upon the special requirements of the location.

The stresses upon the ropes of inclined planes may be determined from the subjoined table, but it should be borne in mind that while the table is based upon an allowance of 40 pounds per ton for rolling friction, there will be an additional stress due to the weight of the rope, proportional to the length of the plane:

STRESS IN HOISTING ROPES ON INCLINED PLANES OF VARIOUS DEGREES.

Rise per 100 ft. horizontal.	Angle of inclination.	Stress in pounds per ton of 2,000 pounds.	Rise per 100 ft. horizontal.	Angle of inclination.	Stress in pounds per ton of 2,000 pounds.
Ft.			Ft.		
5	2° 52′	140	105	46° 24′	1484
10	5° 43′	240	110	47° 44′	1516
15	8° 32′	336	115	49° 00′	1535
20	11° 10′	432	120	50° 12′	1573
25	14° 03′	527	125	51° 21′	1597
30	16° 42′	613	130	52° 26′	1620
35	19° 18′	700	135	53° 29′	1642
40	21° 49′	782	140	54° 28′	1663
45	24° 14′	860	145	55° 25′	1682
50	26° 34′	933	150	56° 19′	1699
55	28° 49′	1003	155	57° 11′	1715
60	30° 58′	1067	160	58° 00′	1730
65	33° 02′	1128	165	58° 47′	1744
70	35° 00′	1185	170	59° 33′	1758
75	36° 53′	1238	175	60° 16′	1771
80	38° 40′	1287	180	60° 57′	1782
85	40° 22′	1332	185	61° 37′	1794
90	42° 00′	1375	190	62° 15′	1804
95	43° 32′	1415	195	62° 52′	1813
100	45° 00′	1450	200	63° 27′	1822

Track Rollers.

THE style and disposition of the track rollers for supporting the rope is an important consideration. Ordinarily they are of wood, from 5 to 8 inches in diameter, and from 10 to 18 inches long (Fig. 139), with ⅞″ or 1″ axles. Gumwood, as a rule, is preferred. The bearings are generally mere blocks of wood, although for permanent work it is advisable to make them of iron. These rollers are spaced from 15 to 30 feet apart, the distance depending largely on the contour of the ground; the closer distances being observed on convex slopes, and the greater distances on straight grades and concave slopes. Steep slopes, with straight, even grades, require fewer rollers than those with lighter grades. On steep or concave slopes the distance between the rollers may often be from 40 to 50 feet, and if the concavity is greater than the catenary corresponding to the tension of the empty cars, the rollers may be omitted altogether without detriment to the rope, as it lifts clear of the ground the moment it is under tension. It very frequently happens, in underground lines where there is a concave dip, that rollers have to be placed above the tracks to prevent the rope scraping against the roof of the gangway. In such cases iron rollers are generally used.

The expense of keeping up these rollers in long lines often amounts to considerable, and for this reason they do not always receive the best attention; but to neglect them is poor economy.

Fig. 140 represents a very good type of track roller. A wooden cylinder fits into iron rings at each end. The axle consists of a bolt with a collar at one end and a nut at the other, the ends being turned down. The hole in the wooden cylinder is large enough to allow the axle to pass through easily, but fits tightly in the iron rings at each end. On the inside of the end rings are ribs which imbed themselves in the wood

Fig. 144.

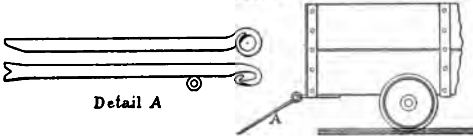


Fig. 145.

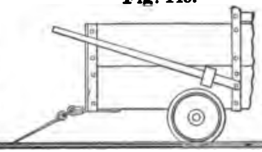
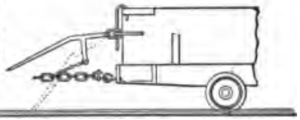


Fig. 146.



Various Styles of Growlers.

Ordinary Wooden Track Roller.

Fig. 139.

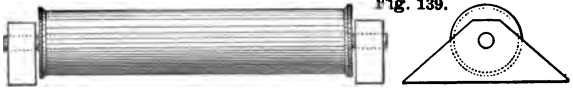
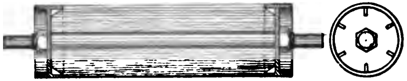
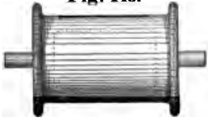


Fig. 140.



Wooden Track Roller with Iron Bands.

Fig. 143.



Iron Cylinder Roller.

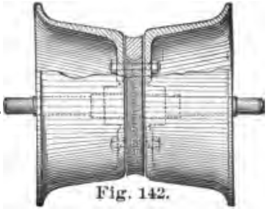
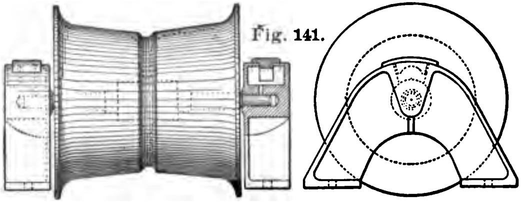


Fig. 142.

Fig. 141.



Iron Track Roller.

Iron Track Rollers.

when the nut is screwed up. These rollers not only give better service than the ordinary wooden roller, but as the cylinders wear out they can be quickly replaced by new ones.

Iron rollers are generally used at points where the greatest wear occurs. Common forms of these are illustrated in Figs. 141, 142 and 143. Fig. 142 shows the same style of roller as Fig. 141, with a removable wearing ring. The roller is made in halves, which are bolted together at the center, and when a ring wears out it is a simple matter to replace it with a new one, thus saving the expense of an entire new roller. This style of roller is recommended for places where the wear is excessive. The track rollers at knuckles should be placed from three to four feet apart, or as close together as possible.

An excellent thing at such points on inclined planes is the arrangement of deflecting and compensating sheaves devised by Eckley B. Coxe, of Drifton, Pa., and illustrated in Figs. 147, 148 and 149. The two sheaves are connected by friction-wheels, as shown, and as either one is moved the other is set in motion in the opposite direction. When the rope, traveling at a high rate of speed, strikes this sheave, it finds it already revolving at the exact speed required, and the heavy friction that with ordinary sheaves would be developed in setting them in motion is thus avoided.

A rope may be guided around curves by rollers or sheaves in two ways, as illustrated in Figs. 150 to 153. Rollers placed between the rails, as in Fig. 151, are usually of cast steel, from 6 to 8 inches in diameter, and mounted in a slightly inclined position on a cast iron base plate, as illustrated in larger scale in Fig. 150. When space will permit, the arrangement shown in Fig. 152 is to be preferred, as the sheaves are less likely to become clogged with dirt than the small rollers, and do not wear out so rapidly.

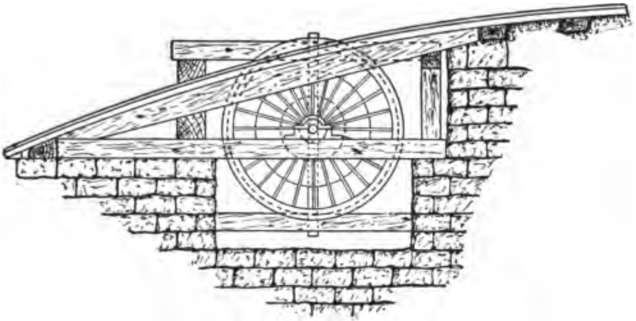


Fig. 147. Side Elevation.

Deflecting and Compensating Sheaves.

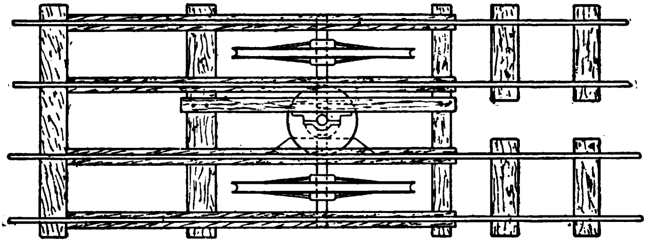


Fig. 148. Plan.

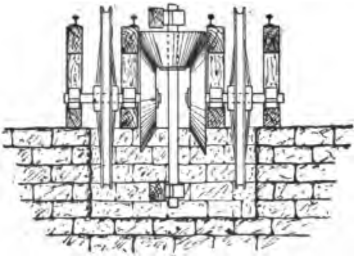


Fig. 149. End Elevation.

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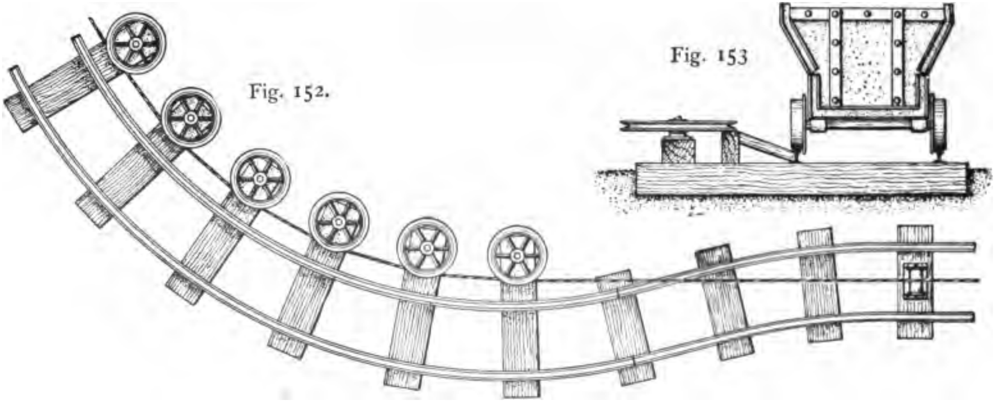


Fig. 152.

Fig. 153

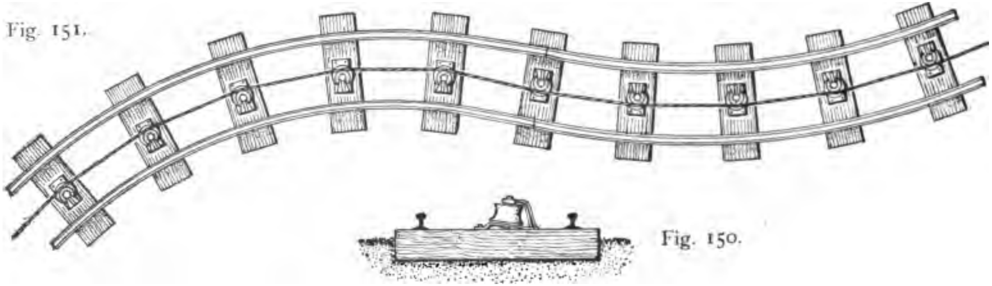


Fig. 151.

Fig. 150.

Mine Cars, Tipples, Etc.

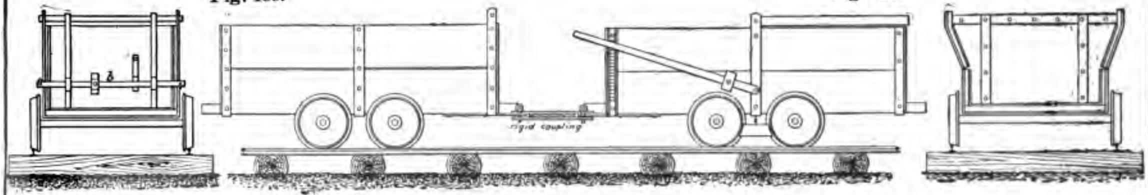
MINE cars are of such various designs that we can only show a few of the commoner types. The car illustrated in Fig. 154 is most generally used in bituminous coal mines. The door is hinged at the ends of the middle band, and when the car is run on to the tipple, the upper band of the door catches in a hook, which opens it in the act of tipping. Where the entries are narrow, the box form of car, shown in Fig. 155, is preferred. The door of this car is hinged to a rod connecting the ends of the front band, requiring a lock-bar, which has to be knocked out as the car is run on to the tipple. The lumps of coal are more apt to clog in such cars than in those with doors hinged to the middle band. Fig. 156 represents a car without any door, used in mines with low roofs, the front end having an inclined board in the bottom, as indicated by the dotted lines, which occasions a loss of some space. Fig. 157 illustrates a car adapted to narrow gauge tracks.

Sometimes the cars are furnished with brakes, as shown in Fig. 154. The manner of coupling the cars is a feature worthy of notice; the simplest coupling consists of a short chain, with hooks at each end, but it is more common to use clevises. Sometimes rigid bars are used, especially where the grades are such that the cars are likely to run together.

The attachment of the front car to the rope is usually made by means of a chain from 2 to 4 feet long, socketed to the rope, and provided with a clevis or hook—Figs. 158 and 159. This chain saves the rope from kinking, owing to the end being tossed about more or less in attaching and detaching; and even when so provided this end of the rope will wear more rapidly than any other portion, so that as it gives out short pieces are cut off or the rope turned ends about and re-socketed.

Fig. 155.

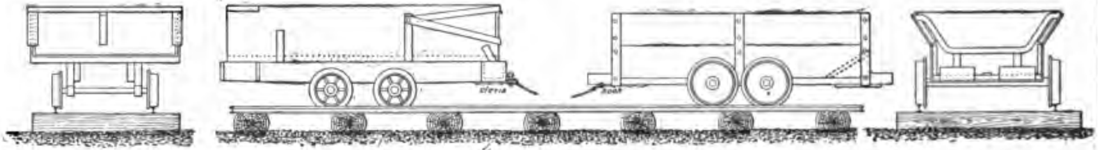
Fig. 154.



Various Styles of Mine Cars.

Fig. 157.

Fig. 156.



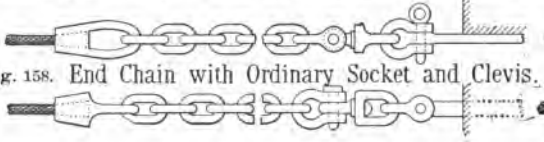


Fig. 158. End Chain with Ordinary Socket and Clevis.

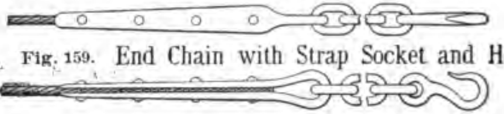


Fig. 159. End Chain with Strap Socket and Hook.

A few words in regard to tipples will not be amiss. The ordinary tipple consists simply of a small platform, pivoted and counterweighted in such a way that when the mine cars are run on to it, their weight overbalances the tipple counterweights, causing them to tilt and discharge over screens or crushers, into bins or cars, as the case may be. The rails on the tipple are turned up at the ends to fit the wheels of the mine cars, and hold them in place during the act of discharging.

Figs. 160 and 161 illustrate an arrangement of tipple, provided with a brake lever and ratchet, by means of which the cars can be dumped by the weighmaster. The counterweight beam, *c*, which is suspended from the front end of the tipple beam, *b*, hangs between two horizontal beams, *e* and *h*, the former being stationary, while the latter is hinged at one end. The opposite end of the beam, *h*, is attached to a rod that leads to the operating lever, *L*, in the weighmaster's office. This lever is provided with a ratchet and pawl, as shown, by means of which the tipple is securely held until the weighmaster is ready to tip. With this tipple, the coal, instead of being discharged in a mass suddenly over the screens, as with the ordinary tipple, may be dumped gradually, causing less breakage and giving a more thorough screening.

Figs. 162 and 163 illustrate a patent coal tipple, controlled in a similar manner, in which the cars are held in the act of dumping by a rod attached to a coil spring. This rod is hooked into the draw bar of the car. As soon as the car is dumped and has righted, the car is unhooked and shoved ahead over the tipple. A sharp inclination in the track at the end, in conjunction with an automatic switch, operates to bring the car back on the side track, the tracks being laid on a slightly descending grade. It is claimed that runs of 300 tons per hour can be made over one of these tipples by one man.

Most inclined planes are provided with safety devices of some kind to guard against accidents. Of these a variety have been devised, but all those depending on throwing the cars from the track by means of obstructions, mechanically placed on the track, are crude and unreliable. This may also be said of the safety switches, which to be effective, are thrown into position by the engineer after the accident happens. The only

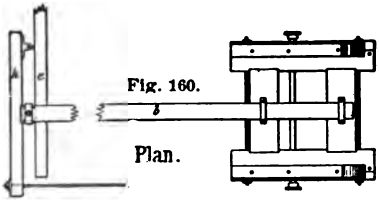


Fig. 160.

Plan.

Tipple with Operating Lever.

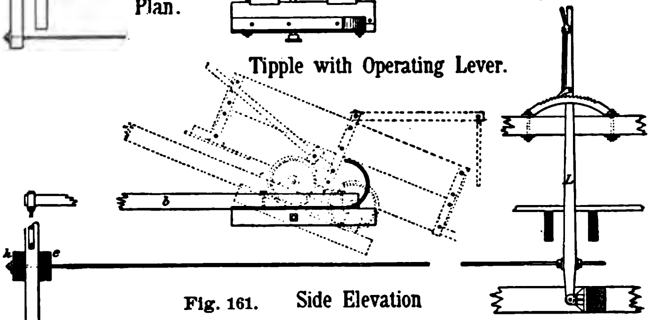


Fig. 161. Side Elevation

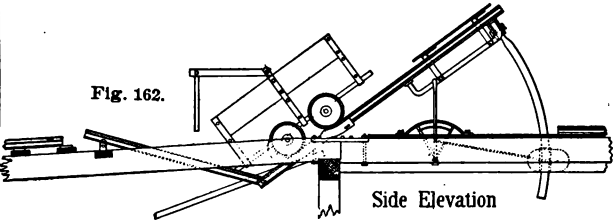


Fig. 162.

Side Elevation

Automatic Tipple.

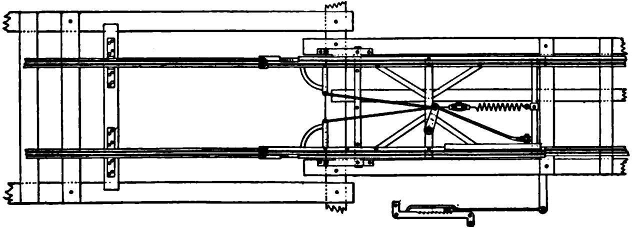


Fig. 163. Plan.

reliable safety switch is that which the engineer or operator must open to allow the cars to pass down the main track, and which closes automatically after the ascending cars pass. A switch of this kind is shown in Fig. 121, page 43. In gravity planes a block is frequently used in the center of the track, as a safeguard to prevent the cars running off on the incline before they are properly attached to the ropes. This block is counterweighted in such a way that it always projects up in the center of the track, and must be pressed down out of the way, when the cars are ready to descend, which is done by means of a lever at one side of the tracks. The best safety appliance for planes where the load is an ascending one, is the old-fashioned "growler," which consists of an iron bar about two inches square and from four to five feet long, attached to the draw bar of the last car, and which drags over the ground and track rollers as long as the cars are running ahead. In case of a breakage of rope or coupling chains, this bar, which is pointed at the end, is immediately driven into the ground, and thus prevents the cars from running back down the slope. In some mines this bar is called the "doctor"; in fact it goes by a variety of names. Several styles of these "growlers" are shown in Figs. 144 to 146, page 56.

Estimates of cost of equipment for surface and underground haulage lines will be furnished in response to applications stating capacity required and length of line, the number and angles of curves, the maximum grades in favor of or against the loads, and the difference in elevation of terminal points. A question sheet is inserted for the convenience of applicants.

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The Bleichert Wire Rope Tramway,

AND OTHER SYSTEMS OF AERIAL TRANSPORTATION.

Bleichert Tramway of Ludwig Mond,
Victoria Mines, Ontario, Canada.

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WIRE ROPE.

Effect of Bending upon Wire Rope

AND ITS APPLICATION TO THE

Transmission of Power.

Suspension Bridges and Wire Cable Ferries.

Wire Rope Fittings, Sheaves and Tackle Blocks.

By WILLIAM HEWITT, M.E.

THE TRENTON IRON COMPANY,
Trenton, N. J.

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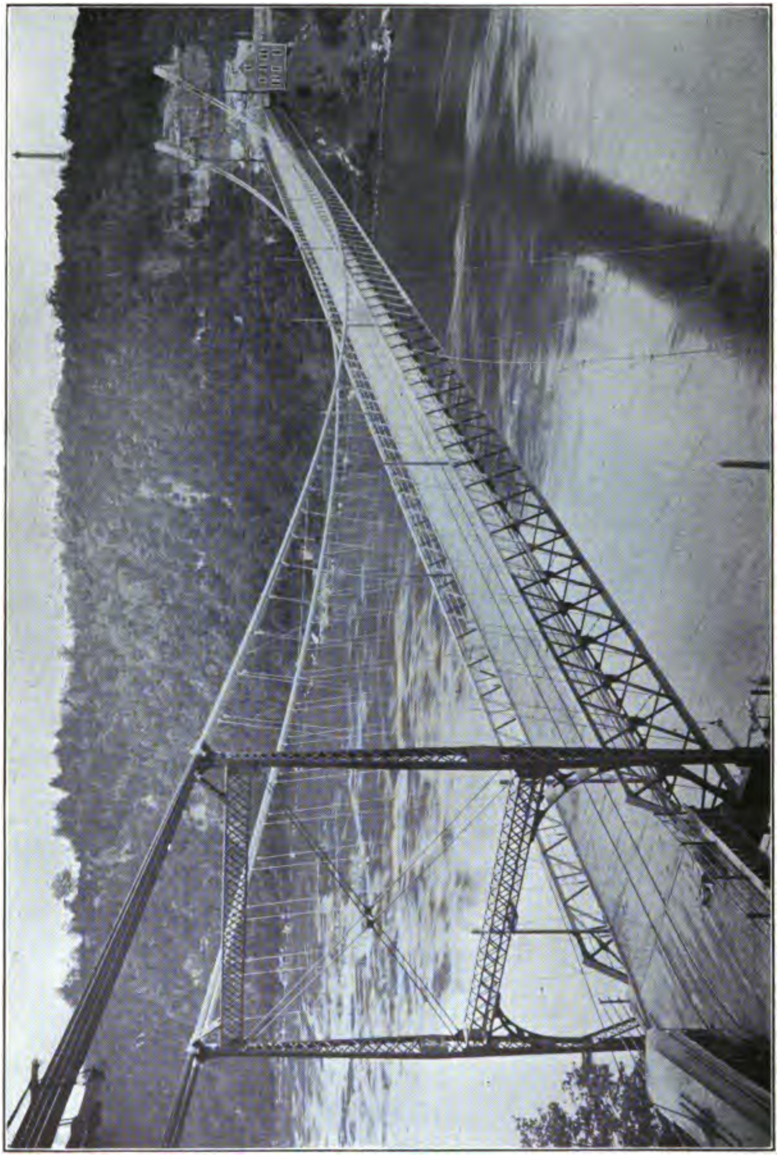


Suspension Bridge across the Niagara Gorge at Lewiston, N. Y.

WIRE ROPE

ORDINARY wire rope is composed of six strands, each containing seven or nineteen wires, laid up about a hemp or wire strand core, and is commonly designated by the number of wires composing its strands, as "seven-wire" or "nineteen-wire" rope, as the case may be.

Rope made with a hemp core is more pliable than that made with a wire core, and is therefore better adapted to purposes where it has to run around sheaves.

The nineteen-wire rope is more flexible than the seven-wire rope, and for the same load stress, therefore, may be run without detriment around smaller sheaves; on the other hand, it is not as well adapted to withstand abrasion or surface wear, and where this is the chief consideration the seven-wire rope is to be preferred; as also for the transmission of power, where the rope is run at a high speed, since the surface wear increases proportionately with the speed.

For special purposes, ropes of twelve and sixteen wires to the strand are made which are intermediate in flexibility between the seven and nineteen-wire ropes.

We make a rope of eight nineteen-wire strands, to meet the demand for a more flexible rope than the ordinary hoisting rope and one better adapted to withstand severe bending. This rope, made of plow-steel wires, has met with much favor for logging machines on which comparatively small drums are used.

Hawser ropes are made of six strands, each of which is composed of twelve wires laid about a hemp core.

Tiller ropes, which are the most flexible of all, are composed of six small seven-wire ropes laid about a hemp core.

In cases where it is desirable to obtain great tensile strength without increasing the diameter and weight of the rope, we recommend the "plow-steel" grade, which will safely bear a stress of 100 to 150 tons per square inch of wire sectional area. This increase in strength however is gained at the sacrifice of some pliability, and it is also to be noted, that since the wires are made of a high grade of cast steel, very carefully tempered, its molecular structure is more apt to be disturbed by undue stress, if not actually destroyed, and is more seriously affected by rust and corrosion than the ordinary grades of cast steel, so that *it is vitally necessary that the sheaves for this rope should be of ample diameter, and that the rope itself should receive the best of care.* Before applying this grade of rope it will be well to confer with us as to its suitability for the proposed service.

The foregoing grades of rope made of galvanized wires (wires coated with zinc to prevent oxidation) are used for special purposes, such as suspension bridge cables, where a high grade of material is required; what is commonly known as "Galvanized Wire Rope," however, such as is used for the standing rigging of ships, derrick guys, etc., is made of a cheaper material, laid up in six strands of either seven or twelve wires each. For both of these purposes the latter rope has superseded hemp rope, since it is more durable, stretches less with changes of weather, and for rigging possesses the further advantage of much less bulk than hemp rope of equal strength. Galvanized guy rope should never be used as a running rope. Wire ropes are made however, especially galvanized for such purposes, and are known on the market as "Galvanized Running Rope."

Wire rope should not be coiled or uncoiled like hemp rope. When it is wound upon a reel, the reel should revolve on a spindle while the rope is paid off; when laid up in a coil, not on a reel, roll the coil on the ground, like a wheel, and pay off the rope in that manner, so that there will be no danger of untwisting or "kinking."

To preserve wire rope, cover it thoroughly with *raw linseed oil,* or with a paint made of equal parts of linseed oil and lamp black; when run underground or in places where it comes in contact with water it should be saturated with pine tar, applied hot, or with coal tar neutralized with slaked lime, using a bushel of fresh slaked lime to a barrel of tar. A number of compounds expressly prepared for covering wire ropes are offered by parties making a specialty of such materials.

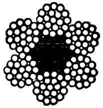
We make our own wire, and the best quality of material only is used in our ropes. The wire used in our cast steel ropes is made from a special grade of steel that combines in a high degree ductility and tensile strength, and is subjected to careful tests to insure uniformly good quality.

"LANG-LAY" ROPE.

A preference has recently been manifested both in this country and abroad for the use, under certain conditions, of a style of wire rope differing from the ordinary wire rope in the manner of laying up. In wire rope, as ordinarily made the component strands are laid up into rope in a direction opposite to that in which the wires are laid into strands; that is, if the wires in the strands are laid from right to left, the strands are laid into rope from left to right. In the particular style of rope above referred to, the wires are laid into strands and the strands into rope in the same direction; that is, if the wire is laid in the strands from right to left, the strands are also laid into rope from right to left. The illustrations on page 13 show the difference between the two methods of laying up. In England this style of rope has been known as "Lang-lay"; in this country, sometimes as "Lang-lay" and sometimes as "Universal-lay." Its use has been found desirable under certain conditions and for certain purposes mostly for haulage plants, inclined planes, and street railway cables, although it has also been used for vertical hoists in mines, etc. Its advantages are that it is somewhat more flexible than rope of the same diameter and composed of the same number of wires laid up in the ordinary manner; and (especially) that owing to the fact that the wires are laid more axially in the rope, longer surfaces of the wires are exposed to wear, and the endurance of the rope is thereby increased. The difference

PLIABLE HOISTING ROPE.

6 Strands of 19 Wires Each.



CAST STEEL. Composed of wires having a tensile strength per sq. in. of 150000 lbs. to 200000 lbs.						IRON. Composed of wires having a tensile strength per sq. in. of 75000 lbs. to 90000 lbs.					
Diameter in inches.	Approximate circumference in inches.	Estimated weight per foot in lbs.	Approximate breaking stress in lbs.	Max. safe stress in lbs. = ⅓ ult. stress.	Proper working load.	Diameter in inches.	Approximate circumference in inches.	Estimated weight per foot in lbs.	Approximate breaking stress in lbs.	Max. safe stress in lbs. = ⅓ ult. stress.	Proper working load.
2¼	7⅛	8.00	312000	104000	Max. safe stress less bending stress determined by the tables page 20.	2¼	7⅛	8.00	156000	52000	Max. safe stress less bending stress determined by the tables page 20.
2	6¼	6.30	248000	82667		2	6¼	6.30	124000	41333	
1¾	5½	4.85	192000	64000		1¾	5½	4.85	96000	32000	
1⅝	5	4.15	168000	56000		1⅝	5	4.15	84000	28000	
1½	4¾	3.55	144000	48000		1½	4¾	3.55	72000	24000	
1⅜	4¼	3.00	124000	41333		1⅜	4¼	3.00	62000	20667	
1¼	4	2.45	100000	33333		1¼	4	2.45	50000	16667	
1⅛	3½	2.00	84000	28000		1⅛	3½	2.00	42000	14000	
1	3	1.58	68000	22667		1	3	1.58	34000	11333	
⅞	2¾	1.20	52000	17333		⅞	2¾	1.20	26000	8667	
¾	2¼	0.89	38800	12933		¾	2¼	0.89	19400	6467	
⅝	2	0.62	27200	9067		⅝	2	0.62	13600	4533	
9/16	1¾	0.50	22000	7333		9/16	1¾	0.50	11000	3667	
½	1½	0.39	17600	5867		½	1½	0.39	8800	2933	
7/16	1¼	0.30	13600	4533		7/16	1¼	0.30	6800	2267	
⅜	1⅛	0.22	10000	3333		⅜	1⅛	0.22	5000	1667	
5/16	1	0.15	6800	2267		5/16	1	0.15	3400	1133	
¼	¾	0.10	4800	1600		¼	¾	0.10	2400	800	

TRANSMISSION OR STANDING ROPE.

6 Strands of 7 Wires Each.

CAST STEEL.

Composed of wires having a tensile strength per sq. in. of 150000 lbs. to 190000 lbs.

Diameter in inches.	Approximate circumference in inches.	Estimated weight per foot in lbs.	Approximate breaking stress in lbs.	Max. safe stress in lbs. $=\frac{1}{3}$ ult. stress.	Proper working load.
1 1/2	4 3/4	3.55	136000	45333	Max. safe stress less bending stress determined by the tables page 21.
1 3/8	4 1/4	3.00	116000	38667	
1 1/4	4	2.45	96000	32000	
1 1/8	3 1/2	2.00	80000	26667	
1	3	1.58	64000	21333	
7/8	2 3/4	1.20	48000	16000	
3/4	2 1/4	0.89	37200	12400	
11/16	2 1/8	0.75	31600	10533	
5/8	2	0.62	26400	8800	
9/16	1 3/4	0.50	21200	7067	
1/2	1 1/2	0.39	16800	5600	
7/16	1 1/4	0.30	13200	4400	
3/8	1 1/8	0.22	9600	3200	
5/16	1	0.15	6800	2267	
9/32	7/8	0.125	5600	1867	

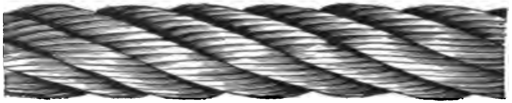
IRON.

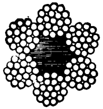
Composed of wires having a tensile strength per sq. in. of 75000 lbs. to 90000 lbs.

Diameter in inches.	Approximate circumference in inches.	Estimated weight per foot in lbs.	Approximate breaking stress in lbs.	Max. safe stress in lbs. $=\frac{1}{3}$ ult. stress.	Proper working load.
1 1/2	4 3/4	3.55	68000	22667	Max. safe stress less bending stress determined by the tables page 21.
1 3/8	4 1/4	3.00	58000	19333	
1 1/4	4	2.45	48000	16000	
1 1/8	3 1/2	2.00	40000	13333	
1	3	1.58	32000	10667	
7/8	2 3/4	1.20	24000	8000	
3/4	2 1/4	0.89	18600	6200	
11/16	2 1/8	0.75	15800	5267	
5/8	2	0.62	13200	4400	
9/16	1 3/4	0.50	10600	3533	
1/2	1 1/2	0.39	8400	2800	
7/16	1 1/4	0.30	6600	2200	
3/8	1 1/8	0.22	4800	1600	
5/16	1	0.15	3400	1133	
9/32	7/8	0.125	2800	933	

ROPES OF HIGH TENSILE STRENGTH.

6 strands of 19 wires each.





EXTRA STRONG CAST STEEL.

Composed of wires having a tensile strength per sq. in. of 190000 lbs. to 225000 lbs.

Diameter in inches.	Approximate circumference in inches.	Estimated weight per foot in lbs.	Approximate breaking stress in lbs.	Max. safe stress in lbs. = ⅓ ult. stress.	Proper working load.
2¼	7⅛	8.00	364000	121333	Max. safe stress less bending stress determined by the tables page 20.
2	6¼	6.30	288000	96000	
1¾	5½	4.85	224000	74667	
1⅝	5	4.15	194000	64667	
1½	4¾	3.55	168000	56000	
1⅜	4¼	3.00	144000	48000	
1¼	4	2.45	116000	38667	
1⅛	3½	2.00	98000	32667	
1	3	1.58	78000	26000	
⅞	2¾	1.20	60000	20000	
¾	2¼	0.89	44000	14667	
⅝	2	0.62	31600	10533	
9/16	1¾	0.50	25400	8467	
½	1½	0.39	20200	6733	
7/16	1¼	0.30	15600	5200	
⅜	1⅛	0.22	11560	3853	
5/16	1	0.15	8100	2700	
¼	¾	0.10	5400	1800	

"PLOW STEEL."

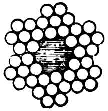
Composed of wires having a tensile strength per sq. in. of 225000 lbs. to 275000 lbs.

Diameter in inches.	Approximate circumference in inches.	Estimated weight per foot in lbs.	Approximate breaking stress in lbs.	Max. safe stress in lbs. = ⅓ ult. stress.	Proper working load.
2¼	7⅛	8.00	416000	138667	Max. safe stress less bending stress determined by the tables page 20.
2	6¼	6.30	330000	110000	
1¾	5½	4.85	256000	85333	
1⅝	5	4.15	222000	74000	
1½	4¾	3.55	192000	64000	
1⅜	4¼	3.00	164000	54667	
1¼	4	2.45	134000	44667	
1⅛	3½	2.00	112000	37333	
1	3	1.58	88000	29333	
⅞	2¾	1.20	68000	22667	
¾	2¼	0.89	50000	16667	
⅝	2	0.62	36000	12000	
9/16	1¾	0.50	29000	9667	
½	1½	0.39	22800	7600	
7/16	1¼	0.30	17700	5900	
⅜	1⅛	0.22	13100	4367	

See remarks page 6.

ROPES OF HIGH TENSILE STRENGTH.

6 Strands of 7 Wires Each.



EXTRA STRONG CAST STEEL.

Composed of wires having a tensile strength per sq. in. of 190000 lbs. to 225000 lbs.

Diameter in inches.	Approximate circumference in inches.	Estimated weight per foot in lbs.	Approximate breaking stress in lbs.	Max. safe stress in lbs. = ⅓ ult. stress.	Proper working load.
1½	4¾	3.55	158000	52667	Max. safe stress less bending stress determined by the tables page 21.
1⅜	4¼	3.00	136000	45333	
1¼	4	2.45	112000	37333	
1⅛	3½	2.00	92000	30667	
1	3	1.58	74000	24667	
⅞	2¾	1.20	56000	18667	
¾	2¼	0.89	42000	14000	
11/16	2⅛	0.75	36800	12267	
⅝	2	0.62	30200	10067	
9/16	1¾	0.50	24600	8200	
½	1½	0.39	19400	6467	
7/16	1¼	0.30	15000	5000	
⅜	1⅛	0.22	11160	3720	
5/16	1	0.15	7760	2587	
9/32	⅞	0.125	6440	2147	

"PLOW STEEL."

Composed of wires having a tensile strength per sq. in. of 225000 lbs. to 275000 lbs.

Diameter in inches.	Approximate circumference in inches.	Estimated weight per foot in lbs.	Approximate breaking stress in lbs.	Max. safe stress in lbs. = ⅓ ult. stress.	Proper working load.
1½	4¾	3.55	182000	60667	Max. safe stress less bending stress determined by the tables page 21.
1⅜	4¼	3.00	156000	52000	
1¼	4	2.45	128000	42667	
1⅛	3½	2.00	106000	35333	
1	3	1.58	84000	28000	
⅞	2¾	1.20	64000	21333	
¾	2¼	0.89	48000	16000	
11/16	2⅛	0.75	42000	14000	
⅝	2	0.62	34000	11333	
9/16	1¾	0.50	28000	9333	
½	1½	0.39	22000	7333	
7/16	1¼	0.30	17100	5700	
⅜	1⅛	0.22	12700	4233	

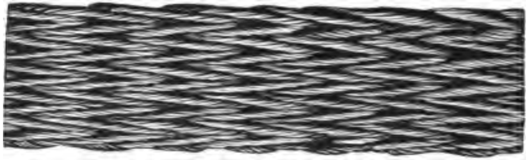
See remarks page 6.

GALVANIZED WIRE ROPE

For Ships' Rigging, Guys for Derricks, Etc.

6 Strands of 7 or 12 Wires Each.

Circumference in inches.	Approximate diameter in inches.	Estimated weight per foot in pounds.	Circumference of hemp rope of equal strength in inches.	Breaking stress in tons of 2000 pounds.
5½	1¾	4.85	11	44
5¼	1 11/16	4.40	10½	40
5	1⅝	4.00	10	36
4¾	1½	3.60	9½	32
4½	1 7/16	3.25	9	29
4¼	1⅜	2.90	8½	26
4	1¼	2.55	8	23
3¾	1 3/16	2.25	7½	20
3½	1⅛	1.95	6½	18
3¼	1 1/16	1.70	6	15
3	1	1.44	5¾	13
2¾	⅞	1.21	5¼	11
2½	13/16	1.00	5	9
2¼	¾	0.81	4¾	7.3
2	⅝	0.64	4½	5.8
1¾	9/16	0.49	3¾	4.4
1½	½	0.36	3	3.2
1¼	7/16	0.25	2½	2.3
1⅛	⅜	0.20	2¼	1.8
1	5/16	0.16	2	1.4
⅞	9/32	0.123	1¾	1.1
¾	¼	0.09	1½	0.81
⅝	7/32	0.063	1¼	0.56
½	3/16	0.04	1⅛	0.36



FLAT ROPES.

Size in inches.	Approximate weight per foot in pounds.	Breaking stress (approximate) in pounds.	
		Iron.	Cast steel.
2 x⅜	1.35	20000	40000
2½x⅜	1.70	25000	50000
3 x⅜	2.05	30000	60000
3½x⅜	2.40	35000	70000
4 x⅜	2.75	40000	80000
5 x⅜	3.45	50000	100000
6 x⅜	4.15	60000	120000
3 x½	2.40	37500	75000
3½x½	2.85	43750	87500
4 x½	3.30	50000	100000
5 x½	4.20	62500	125000
6 x½	5.10	75000	150000
7 x½	6.00	87500	175000
8 x½	6.90	100000	200000

For safe working load allow from one-fifth to one-seventh of the breaking stress.

between the "Lang-lay" and the ordinary lay wire rope when new, and the appearance of the former after being subjected to a lengthened period of wear, are shown in the subjoined illustrations. The ordinary rope shows in use a tendency in the component wires to break on the crowns of the strands, which tendency is in the "Lang-lay" rope very much diminished. In consequence of its greater flexibility, moreover, fewer wires may be used in the strands of the "Lang-lay" rope; in fact it is almost always made with seven wires to the strand, although occasionally with twelve. There are, on the other hand, some drawbacks to the use of the "Lang-lay" rope; it cannot be spliced to a rope of the ordinary lay, and it is in itself somewhat more difficult to handle and splice, owing to the fact that great care has to be taken to prevent unwinding of the strands, which is apt to occur unless the rope is well served or otherwise secured behind the place where the splice is to be made.

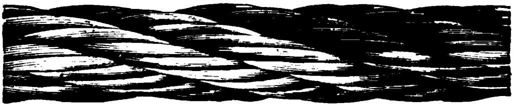


Fig. 201. Rope of Ordinary Lay, New.

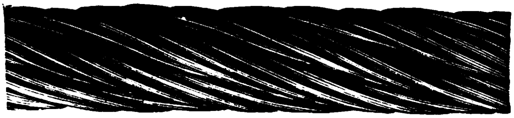


Fig. 202. "Lang-lay" Rope, New.

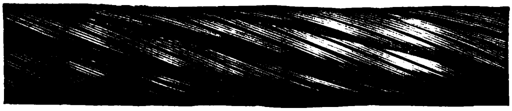


Fig. 203. "Lang-lay" Rope, Worn.

Messrs. Trenton Iron Co., Trenton, N. J. SOUTH PITTSBURG, Tenn., October 13, 1896.

DEAR SIR—Your [sixteen-wire Lang-lay] rope, which was placed on our Whitewell Incline in September, 1894, is still in use, and has now, by far, the best record of any rope we have ever used on that Incline.

Yours truly,

TENNESSEE COAL, IRON & R. R. CO.

[Signed] Jas. L. Gaines, *A. G. M.*

PATENT LOCKED-WIRE ROPE.

Fig. 204 illustrates the construction of our Patent Locked-Wire Rope, so named from the fact that the exterior wires are drawn to such a shape that each one interlocks with its neighbor, presenting a smooth cylindrical surface like a solid round bar. This rope will, under normal conditions, not only outwear two or three ordinary ropes of the same size, but, on account of its smooth surface, the life of the sheaves and rollers over which it runs, or which run upon it, as the case may be, is also proportionately greater, which is often quite as important as the life of the rope itself. The wires are made of the best tempered cast steel, and it is evident that with this construction such a thing as unstranding is impossible. Should any of the wires break, which rarely happens, it cannot result in projecting ends and a ragged surface as in the case of ordinary ropes. Another advantage it possesses is that it has no tendency to twist in working as ordinary ropes have. These ropes have wire cores, and on this account are somewhat stiffer than ordinary ropes of the same size; but they are also much stronger. Compared with ordinary ropes of equal strength, the locked-wire rope is quite as flexible. In the ordinary ropes the strength is only about 80 per cent. of the aggregate strength of the individual wires, whereas in the locked-wire rope it is about 95 per cent., and in substituting the locked-wire ropes for ordinary ropes, therefore, a size smaller should be used. *This rope cannot be spliced like ordinary rope.*

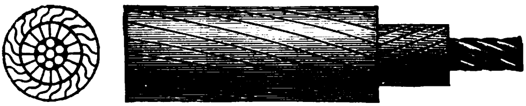


Fig. 204. Patent Locked-Wire Rope.

Inquiries for locked-wire rope should always state the purpose for which it is intended, diameter of drums and sheaves employed, and size and style of rope hitherto used.

PATENT LOCKED-WIRE ROPE.

CAST STEEL.

Diameter in Inches.	Estimated Weight per Foot, in Pounds.	Approximate Breaking Stress, in tons of 2,000 Pounds.	Proper Working Load in tons of 2,000 Pounds.	Minimum Diameter of Drum or Sheave, in Feet.
2	10.00	170	34.00	
1¾	7.65	129	26.00	
1½	5.70	95	19.00	12
1⅜	4.75	80	16.00	10
1¼	3.80	67	13.40	9
1⅛	3.15	55	11.00	8
1	2.50	43	8.60	7
⅞	1.88	36	7.20	6
¾	1.38	27	5.40	5½
⅝	0.90	19	3 80	5
9/16	0.72	13¼	2.65	4½
½	0.57	11½	2.30	4

For larger sheaves than given in the table the proper working load will be one-third the ultimate stress less the bending stress. The bending stress for ⅞″ diameter and larger is about the same as for twelve-wire ordinary rope which is intermediate between the seven-wire and nineteen-wire rope, and for the smaller sizes about the same as for seven-wire rope. We do not recommend smaller sheaves, even though the load stress may be correspondingly less than that given in the table as the proper working load.

This rope is particularly recommended for stationary cables serving as a track for carriages to run upon in aerial systems of transportation, especially for that class known as Cable Hoist-Conveyors. Its adaptability for this purpose is attested by the following testimonial letters:

Trenton Iron Co., Trenton, N. J. LOUISVILLE, Ky., April 5th, 1899.

GENTLEMEN—Replying to your favor of the 31st ultimo. We have found the Patent Locked-Wire Rope superior to the ordinary rope, and the one we now have in use is giving entire satisfaction.

Yours respectfully,
DENNIS, LONG & COMPANY,
By E. P. Koetter.

Extract from a letter from W. I. STEEL, December 19, 1899, relating to an interview with
DENNIS, LONG & CO.

"I called on these people and saw the cableway which you built. Our Patent Locked Rope is working fine. It was put in, I understand, in '93, and since then has carried on an average 400 tons daily, and the superintendent stated that from present appearances the rope was good for twenty-five years. This certainly is a recommendation for the Patent Locked Rope."

Trenton Iron Company, Chicago, Ill.: LEMONT, Ill., 5-13-1896.

GENTLEMEN—Your letter of the 6th inst., received upon the writer's return here.

In reference to the efficiency of the "Patent Locked Cable" furnished us by your Company, will say that results obtained by its use have been very satisfactory to us. We have conveyed an amount of over 80,000 cubic yards over this line with little or no perceptible wear on the cable.

Very respectfully,
MASON, LOCHER & WILLIAMSON,
C. H. Locher.

To Whom it May Concern: ROCKLAND, Me., April 12, 1895.

This is to certify that we have hoisted fully one hundred and fifty thousand (150,000) tons of limestone over the Locked Cable Tramway, erected for us by the Trenton Iron Co., at our Engine Quarry. This output covers a period of about five years, and there is as yet no apparent wear upon the cable.

Yours truly,
COBB LIME CO.,
H. N. Pierce, *Sec'y.*

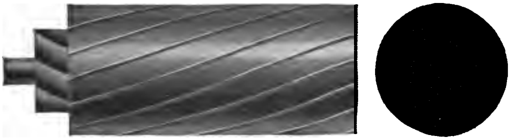


Fig. 205. Patent Locked-Coil Cable.

Fig. 205 illustrates a modification of the locked-wire rope known as the Patent Locked-Coil Cable, which is used expressly as a track cable for wire rope tramways of the Bleichert System, and differs from the locked-wire rope simply in the larger size and fewer number of the wires, and while it is consequently much stiffer than the locked-wire rope, it is sufficiently flexible to be shipped in coils. It is made in lengths up to 1,200 feet, which can be joined by the patent coupling illustrated in Fig. 226, page 41.

THE EFFECT OF BENDING ON WIRE ROPE.

Bending stress.—We are frequently asked "how long a certain rope will last," a question difficult to reply to with any satisfaction, since the life of a wire rope may be affected in various ways. Aside from the duty performed by a wire rope, its life will depend on the care taken of it, its exposure to the corroding action of water, and more especially water containing salts, or acids, etc., factors upon which no calculations can be based.

The causes most destructive to the life of a wire rope are abrasion and excessive bending. Abrasion results in direct injury by the wearing away and mutilation of the wires, as illustrated in Fig. 206, while undue bending is manifested in the fracturing of the outer wires, as in Fig. 207,

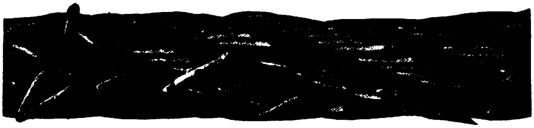


Fig. 206. Wire Rope showing effect of abrasion.

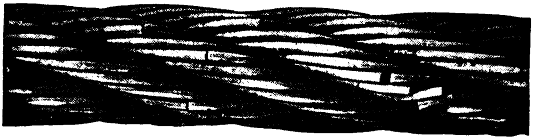


Fig. 207. Wire Rope showing wires broken from undue bending.

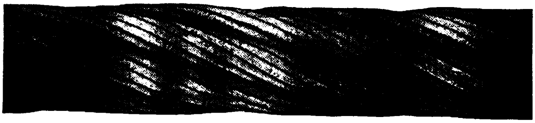


Fig. 208. Wire Rope showing good wear.

before these wires become flattened by service as in Fig. 208. The destructive effect of undue bending has not been sufficiently well understood, and more wire ropes perhaps are brought to an untimely end from this cause than from any other. This is owing to the fact that the lack of space very often precludes the use of sheaves having the requisite diameter for good results. Cases frequently occur, as in the transmission of power, where the bending stress is considerably greater than that due to the useful effort or load, so that the proper size and disposition of the sheaves is a matter that should receive careful consideration in the installation of running ropes.

The curvature should be such that the bending stress resulting therefrom added to the load stress will not produce a tension in the wires exceeding the elastic limit. The bending stress is determined by the formula,

$$k = \frac{E a}{2.06\frac{R}{d} + C}$$

in which, k represents the bending stress in pounds, E the modulus of elasticity = 28,500,000, a the aggregate area of the wires in square inches, R the radius of the bend in inches, d the diameter of the individual wires in inches, and C a constant depending on the number of wires in the strands. The values of d and C are,

For Steel
Iron =
27000000

	7-wire Rope.	19-wire rope.
$d=$	$\frac{1}{9}$ diam. of rope,	$\frac{1}{15}$ diam. of rope,
$C=$	9.27	15.45

For twelve-wire and sixteen-wire ropes the values are intermediate in proportion to the number of wires. In the case of ropes having strands composed of different sizes of wires, take the larger of the outer layer for the value of d. From the above formula have been calculated the tables on pages 20 and 21.

BENDING CURVATURE.—The angle of bend in a wire rope is also a matter for consideration, since the curvature is a function of this angle and the tension, the relations between which may be such as to produce a curvature having a greater radius than the sheave about which it runs. This applies more especially to cases where slight bends are made, and explains how it is that ropes are frequently run around comparatively small rollers without detriment, since it is possible to place these so close that the bending angle on each will result in a curvature that will not overstrain the wires. This curvature may be ascertained from the formula,

$$R = \frac{E\, d^4\, u}{5.25\, t \cos \frac{1}{2}\, \theta}$$

in which, R represents the radius of curvature in inches, E the modulus of elasticity = 28,500,000, d the diameter of the individual wires in inches, u the number of wires in the rope, t the load stress in pounds, and θ the angle of bend $a\,c\,b$, (Fig. 209), between the tangents to the curve at the points of inflection a and b. This formula gives the theoretical radius of curvature for one pound tension, and to determine the actual radius of curvature, in cases where this may exceed the radius of the sheave, it is simply necessary to divide by the actual tension.

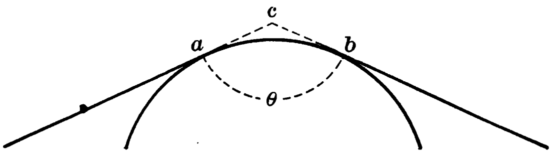


Fig. 209.

The rigidity of the rope, or effect of the internal friction of the wires has not been taken into account, since it is insignificant and it is on the safe side to ignore it. The table on page 22 has been calculated from the above formula.

BENDING STRESSES—19-WIRE ROPE.

Diam. of Bend.	6	8	10	12	14	16	18	20	22	24	26
Diam. of Rope.											
1/4	1946	1474	1187	993	854	749	667	601	547	502	464
5/16	3633	2192	2224	1863	1603	1406	1253	1129	1028	944	872
3/8	......	4097	3306	2771	2385	2093	1865	1682	1532	1406	1299
7/16	......	......	5790	4859	4194	3676	3285	2957	2693	2473	2286
1/2	......	......	......	7125	6142	5397	4814	4344	3958	3635	3360
9/16	......	......	......	......	8971	7888	7038	6354	5790	5319	4918
5/8	......	......	......	......	12546	11037	9852	8897	8111	7452	6893
11/16	......	......	......	......	....	14448	12902	11655	10627	9767	9035
3/4	......	......	......	......	....	....	16516	14925	13612	12512	11577
7/8	......	......	......	......	....	....	....	23161	21136	19436	18375
1	......	......	......	......	....	....	....	....	....	29799	27592
1 1/8	......	......	......	......	....	....	....	....	....	....	38532

Diam. of Bend.	28	30	36	48	60	72	84	96	108	120
Diam. of Rope.										
1/4	431	402	336	252	202	168	144	126	112	101
5/16	810	757	632	475	380	317	272	238	212	191
3/8	1208	1128	942	708	567	473	406	355	316	285
7/16	2125	1985	1658	1247	1000	834	716	627	557	502
1/2	3124	2920	2440	1836	1472	1228	1054	923	821	739
9/16	4574	4275	3573	2690	2157	1800	1545	1353	1203	1084
5/8	6411	5992	5011	3774	3027	2526	2169	1900	1690	1522
11/16	8405	7857	6572	4953	3973	3317	2847	2494	2219	1998
3/4	10771	10071	8427	6352	5098	4257	3654	3201	2848	2565
7/8	16743	15658	13111	9891	7941	6633	5696	4990	4440	3999
1	25689	24032	20136	15205	12214	10206	8766	7681	6836	6158
1 1/8	35886	33580	28153	21276	17099	14293	12278	10761	9578	8689
1 1/4	....	45337	38034	28766	23130	19340	16618	14567	12967	11683
1 3/8	....	....	51609	39067	31430	26290	22594	19811	17637	15893
1 1/2	....	....	66065	50049	40284	33707	28976	25410	22625	20390
1 5/8	....	....	....	62895	50647	42391	36450	31969	28470	25661
1 3/4	....	....	....	79749	64252	53798	46270	40590	36152	32589
1 7/8	....	....	....	97018	78202	65500	56347	49438	44039	39701
2	....	....	....	....	94016	78769	67778	59478	52989	47777
2 1/4	....	....	....	....	134319	112611	96943	85103	75840	68396
2 1/2	....	....	....	....	....	154870	133386	117137	104417	94189

BENDING STRESSES—7-WIRE ROPE.

Diam. of Bend.	10	12	14	16	18	20	22	24	26	28
Diam. of Rope.										
$\frac{1}{4}$	1954	1635	1406	1254	1098	989	900	826	763	709
$\frac{9}{32}$	......	2214	1904	1670	1488	1341	1220	1120	1034	962
$\frac{5}{16}$	......	......	2734	2399	2137	1926	1754	1609	1487	1382
$\frac{3}{8}$	......	......	......	4129	3680	3318	3022	2774	2564	2383
$\frac{7}{16}$	......	......	......	......	5823	5253	4785	4385	4061	3776
$\frac{1}{2}$	......	......	......	......	......	8519	6751	6200	5732	5329
$\frac{9}{16}$	......	......	......	......	......	......	9879	9072	8389	7802
$\frac{5}{8}$	......	......	......	......	......	......	......	......	11756	10935
$\frac{11}{16}$	......	......	......	......	......	......	......	......	....	....

Diam. of Bend.	30	36	48	60	72	84	96	108	120	132
Diam. of Rope.										
$\frac{1}{4}$	662	553	412	333	277	238	208	185	166	151
$\frac{9}{32}$	898	750	563	451	376	323	282	251	226	206
$\frac{5}{16}$	1291	1078	810	649	541	464	406	361	325	296
$\frac{3}{8}$	2226	1859	1398	1120	934	801	702	624	562	511
$\frac{7}{16}$	3528	2982	2217	1777	1482	1272	1113	990	892	811
$\frac{1}{2}$	4980	4161	3131	2510	2095	1797	1574	1400	1260	1146
$\frac{9}{16}$	7291	6095	4589	3679	3071	2635	2308	2053	1848	1681
$\frac{5}{8}$	10221	8547	6438	5164	4310	3699	3240	2882	2595	2360
$\frac{11}{16}$	13058	10922	8230	6603	5513	4731	4144	3687	3320	3020
$\frac{3}{4}$	....	14202	10706	8591	7174	6158	5394	4799	4322	3931
$\frac{7}{8}$	....	22592	17045	13685	11431	9815	8599	7651	6892	6269
1	....	....	25476	20464	17100	14686	12869	11452	10317	9386
$1\frac{1}{8}$	....	....	36289	29165	24416	20942	18355	16336	14718	13391
$1\frac{1}{4}$	....	....	....	40020	33464	28754	25206	22437	20216	18396
$1\frac{3}{8}$	....	....	....	....	44551	38290	33571	29888	26933	24510
$1\frac{1}{2}$	....	....	....	....	57835	49718	43599	38821	34987	31842

RADIUS OF CURVATURE OF WIRE ROPES IN INCHES FOR ONE POUND TENSION.

Divide by actual stress in pounds to obtain actual radius in inches.

19-Wire Rope.	90°	100°	110°	120°	125°	130°	135°	140°	145°	150°	155°	160°
½	1038	1142	1280	1468	1626	1736	1918	2146	2441	2836	3391	4226
⅝	2723	2996	3357	3851	4170	4556	5032	5630	6404	7440	8897	11090
¾	5470	6017	6743	7736	8377	9151	10107	11309	12863	14944	17870	22274
⅞	10605	11666	13074	14998	16240	17742	19596	21925	24938	28974	34647	43184
1	17636	19401	21742	24941	27007	29506	32587	36462	41471	48183	57617	71816
1⅛	27692	30463	34138	39162	42406	46329	51168	57251	65117	75655	90469	112763
1¼	41535	45692	51205	58740	63606	69489	76747	85872	97670	113477	135696	169135
7-Wire Rope.												
½	3171	3488	3909	4485	4856	5306	5859	6556	7457	8663	10360	12914
⅝	7309	8040	9010	10336	11193	12229	13505	15111	17187	19968	23878	29762
¾	15302	16834	18865	21641	23434	25604	28275	31637	35984	41807	49993	62313
⅞	28545	31402	35191	40277	43714	47761	52745	59016	67124	77988	93258	116239
1	48949	53847	60344	69224	74959	81899	90446	101199	115103	133731	159915	199323
1⅛	78721	86598	97047	111328	120551	131712	145457	162751	185111	215069	257180	320556
1¼	123869	136263	152706	175177	189689	207252	228880	256092	291276	338416	404679	504402

19-Wire Rope.	165°	169°	170°	171°	172°	173°	174°	175°	176°	177°	178°	179°
½	5623	7969	8421	9734	10949	12511	14593	16825	21884	29177	43762	87521
⅝	14753	19454	22095	23766	26731	30543	35628	44178	53429	71232	106841	213674
¾	29633	39604	45412	48381	54417	62179	72530	88673	108767	145010	217502	434987
⅞	57451	74736	86040	91298	102688	117336	136869	171917	205251	273644	410440	820849
1	95541	127497	143085	155750	175182	200169	233492	285897	350150	466825	700193	1400363
1⅛	150016	204221	224667	249482	280607	320632	374010	448907	560872	747765	1121574	2243063
1¼	225012	311272	336982	380251	427689	488695	570050	673323	854858	1139710	1709456	3418781
7-Wire Rope.												
½	17179	22653	25727	27673	31125	35564	41485	51405	62212	82942	124405	248800
⅝	39594	55304	59297	67560	75988	86827	101282	118482	151884	202496	303723	607422
¾	82899	114679	124151	140092	157570	180045	210018	248066	314948	419893	629800	1259550
⅞	154641	212457	231593	259538	291917	333556	389085	462745	583479	777903	1164099	2333472
1	265173	362443	397129	442761	497998	569032	663767	793501	995390	1327079	1990478	3980800
1⅛	426459	580563	638674	709227	797697	911480	1063217	1276131	1594422	2125707	3188359	6376414
1¼	671041	884870	1004965	1080959	1215817	1389240	1620513	2008017	2430151	3239913	4859561	9718752

TRANSMISSION OF POWER BY WIRE ROPE.

Rope stresses.—In transmitting power by wire rope, the load stress or working tension should not exceed the difference between the maximum safe stress and the bending stress, as determined by the preceding tables. The load stress may be greater therefore as the bending stress is less, but to avoid slipping a certain ratio must exist between the tensions in taut and slack portions of the rope when running, which is determined by the formula, $T = S e^{f n \pi}$, in which, T represents the tension in the taut portion of the rope, S the tension in the slack portion, e the base of the Naperian system of logarithms $= 2.7182818$, n the number of half laps of the rope about the sheaves or drums at either end of line, $\pi = 3.1416$, and f the co-efficient of friction depending on the kind of filling in the grooves of the sheaves, or character of the material upon which the rope tracks.

The useful effort or transmitting force is the difference between the tension of the taut and slack portions of the rope, $T - S = S\,(e^{f n \pi} - 1)$, and to obtain this, the initial tension or tension when the rope is at rest must be one-half the sum of the two tensions,

$$T + S = S\,(e^{f n \pi} + 1) = \frac{e^{f n \pi} + 1}{e^{f n \pi} - 1}\,(T - S)$$

The following are some of the values of f:

Dry rope on a grooved iron drum,	.120
Wet " " " " "	.085
Greasy " " " " "	.070
Dry " " wood-filled sheaves,	.235
Wet " " " " "	.170
Greasy " " " " "	.140
Dry " " rubber and leather filling,	.495
Wet " " " " " "	.400
Greasy " " " " " "	.205

The values of the co-efficients

$$e^{f n \pi} \text{ and } \frac{e^{f n \pi} + 1}{e^{f n \pi} - 1}$$

corresponding to the above values of *f*, for one up to six half laps of the rope, are as follows:

Values of $e^{fn\pi}$

$f=$	n=number of half laps about sheaves or drums at either end of line.					
	1	2	3	4	5	6
.070	1.246	1.552	1.934	2.410	3.003	3.741
.085	1.306	1.706	2.228	2.910	3.801	4.964
.100	1.369	1.875	2.566	3.514	4.810	6.586
.120	1.458	2.125	3.099	4.518	6.586	9.602
.130	1 504	2.263	3.405	5.122	7.706	11.593
.140	1.552	2.410	3.741	5.808	9.017	13.998
.150	1.602	2.566	4.111	6.586	10.551	16.902
.170	1.706	2.910	4.964	8.467	14.445	24.641
.200	1.875	3.514	6.586	12.346	23 140	43.376
.205	1.904	3.626	6.904	13.146	25.031	47.663
.235	2.092	4.378	9.160	19.166	40.100	83.902
.250	2.193	4.810	10.551	23.140	50.637	111.318
.265	2.299	5.286	12.153	27.941	64.239	147.693
.300	2.566	6.586	16.902	43.376	111.318	285.680
.350	3.001	9.017	27.077	81.307	244.152	733.145
.400	3.514	12.346	43.376	152.405	535.488	1849.140
.410	3.626	13.146	47.663	172.814	626.577	2271.775
.450	4.111	16.902	69.487	285.680	1174.480	4828.510
.495	4.716	22.425	106.194	502.881	2381.400	....
.500	4.810	23 140	111.318	535.488	2575 940	....

Values of $\dfrac{e^{fn\pi}+1}{e^{fn\pi}-1}$

$f=$	n=number of half laps about sheaves or drums at either end of line.					
	1	2	3	4	5	6
.070	9.130	4.623	3.141	2.418	1.999	1.729
.085	7.536	3.833	2.629	2.047	1.714	1.505
.100	6.420	3 287	2.280	1.795	1.525	1.358
.120	5.345	2.777	1.953	1.570	1.358	1 232
.130	4.968	2.584	1.832	1.485	1.298	1.189
.140	4.623	2.418	1.729	1.416	1.249	1.154
.150	4.322	2.280	1.643	1.358	1.209	1.126
.170	3.833	2.047	1.505	1.268	1.149	1.085
.200	3.287	1.795	1.358	1.176	1.090	1.047
.205	3.212	1.762	1.338	1.165	1.083	1.043
.235	2.831	1.592	1.245	1.110	1.051	1.024
.250	2.676	1.525	1.209	1.090	1.040	1.018
.265	2.539	1.467	1.179	1.072	1.032	1 014
.300	2.280	1.358	1.126	1.047	1.018	1.007
.350	2.000	1.249	1.077	1.025	1.008	1.003
.400	1.795	1.176	1.047	1 013	1.004	1.001
.410	1.765	1.164	1.043	1.012	1.003	1.001
.450	1.643	1.126	1.029	1.007	1.002	1.000
.495	1.538	1.093	1.019	1.004	1.001	1.000
.500	1.525	1.090	1.018	1.004	1.001	1.000

It is apparent from the foregoing that for a given diameter of sheave, and a variable diameter of wire, a ratio exists between these diameters corresponding to a maximum working tension. This ratio is one resulting approximately in a working tension of one-third and bending stress of two-thirds of the maximum safe tension, which is from one-third to two-fifths of the ultimate stress, and practically determines the minimum diameter of sheave for any rope. The ratio for any size of wire varies slightly, according to the number of wires composing the rope, and in terms of rope diameter is,

	Steel.	Iron.
For seven-wire rope, ...	79.6	160.5
For twelve-wire rope, ...	59.3	120.
For nineteen-wire rope, ...	47.2	95.8

from which we derive the following table:

DIAMETERS OF MINIMUM SHEAVES IN INCHES.

Diameter of Rope.	STEEL.			IRON.		
	7-Wire.	12-Wire.	19-Wire.	7-Wire.	12-Wire.	19-Wire.
¼	20	15	12	40	30	24
5/16	25	19	15	50	38	30
⅜	30	22	18	60	45	36
7/16	35	26	21	70	53	42
½	40	30	24	80	60	48
9/16	45	33	27	90	68	54
⅝	50	37	30	100	75	60
11/16	55	41	32	110	83	66
¾	60	44	35	120	90	72
⅞	70	52	41	140	105	84
1	80	59	47	160	120	96

Under ordinary conditions, ropes of seven wires to the strand, laid about a hemp core, are best adapted to the transmission of power, but conditions often occur, as noted under the caption "Limits of Span," where twelve-wire or nineteen-wire rope is to be preferred.

DEFLECTIONS OF THE ROPE —The tension of the rope is measured by the amount of deflection or sag at the center of the span, which is determined by the formula,

$$h = \frac{w\ s^2}{8\ t}$$

in which, h represents the deflection in feet, w the weight of the rope per foot in pounds, s the span in feet, and t the tension in pounds. By substituting in this formula the value of $w =$ approximately $\frac{1}{2}\ \pi\ D^2$, (D representing the diameter of the rope), and the values of t as calculated from the formulæ for determining the tensions, the deflections for "flying" transmissions, in which the rope makes a single lap around a driving and driven sheave, are as follows:

	Steel.	Iron.
Def. of still rope at center in feet,	$h = .00004\ S^2$	$h = .00008\ S^2$
" " driving " " " "	$h_1 = .000025\ S^2$	$h_1 = .00005\ S^2$
" " slack " " " "	$h_2 = .0000875\ S^2$	$h_2 = .000175\ S^2$

HORSE-POWER.—The general formula for the amount of power capable of being transmitted is as follows:

$$H.\ P. = [c\ D^2 - .000006\ (W + g_1 + g_2)]\ v$$

in which, D represents the diameter of the rope in inches, v the velocity of the rope in feet per second, W the weight of the rope, g_1 the weight of the terminal sheaves and shafts, g_2 the weight of the intermediate sheaves and shafts (all in pounds), and c a constant depending on the material of the rope, the filling in the grooves of the sheaves or surface upon which the rope tracks, and the number of half laps about the sheaves or drums at either end of line. The values of c for one up to six half laps for steel rope are as follows:

$c =$ for Steel Rope on	Number of half laps about sheaves or drums at either end of line.					
	1	2	3	4	5	6
Iron	5.61	8.81	10.62	11.65	12.16	12.56
Wood	6.70	9.93	11.51	12.26	12.66	12.83
Rubber and Leather	9.29	11.95	12.70	12.91	12.97	13.00

The values of c for iron rope are one-half of the above.

It is evident from the above figures that when more than three laps are made, it is immaterial what the surface is upon which the rope tracks, as far as frictional adhesion is concerned.

From the above formula we have the general rule, that the actual horse power capable of being transmitted by any wire rope approximately equals c times the square of the diameter of the rope in inches, less six-millionths the entire weight of all the moving parts, multiplied by the speed of the rope, in feet per second.

From this rule, assuming the sheaves to be of equal diameter, and of a size not less than the minimum diameter given in the table on page 25, we deduce the following:

TABLE OF HORSE-POWERS

capable of being transmitted by a steel rope making a single lap on wood-filled sheaves.

Diam. of Rope, in inches.	Velocity of Rope in Feet per Second.									
	10	20	30	40	50	60	70	80	90	100
¼	4	8	13	17	21	25	28	32	37	40
5/16	7	13	20	26	33	40	44	51	57	62
⅜	10	19	28	38	47	56	64	73	80	89
7/16	13	26	38	51	63	75	88	99	109	121
½	17	34	51	67	83	99	115	130	144	159
9/16	22	43	65	86	106	128	147	167	184	203
⅝	27	53	79	104	130	155	179	203	225	247
11/16	32	63	95	126	157	186	217	245	.....	.....
¾	38	76	103	150	186	223	.....	.....	.....	.....
⅞	52	104	156	206	.....	.....	.....	.....	.....	.....
1	68	135	202	.....	.....	.....	.....	.....	.....	.....

The horse-power that may be transmitted by iron ropes is one-half of the above.

The above table gives the maximum amount of power capable of being transmitted under the conditions stated, so that in using wood-lined sheaves, it is well to make some allowance for the stretching of the rope, and to advocate somewhat heavier equipments than the above table would give; that is, if it is desired to transmit 20 horse-power, for instance, to put in a plant that would transmit 25 to 30 horse-power, thus avoiding the necessity of having to take up a comparatively small amount of stretch. On rubber and leather filling, however, the amount of power capable of being transmitted is considerably greater than on wood, so that this filling is generally used, and in this case no allowance need be made for stretch, as such sheaves will likely transmit the power given by the table, under all possible deflections of the rope.

The transmission of more than 250 horse-power is impracticable with filled sheaves, since the tension is so great that the filling would quickly cut out, and the frictional adhesion on a metallic surface is insufficient where the rope makes but a single lap, or a half lap at either end of the line. In this case it is necessary to use the Realeaux method, in which the rope makes more than one lap, as referred to under the caption "Long-distance Transmissions."

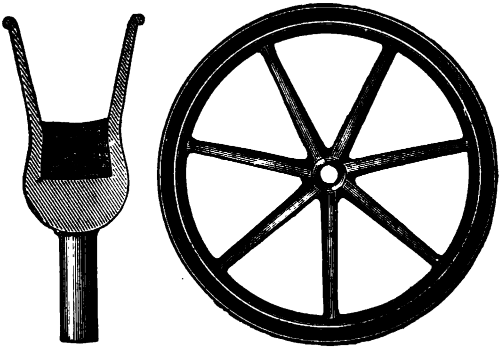


Fig. 210.
Transmission Sheaves.

THE SHEAVES (Fig. 210) are usually of cast iron, and are made as light as possible consistent with the requisite strength. Various materials have been used for filling the grooves, such as tarred oakum, jute yarn, hard wood, rubber and leather. The filling which gives the best satisfaction in ordinary transmissions, consists of segments of leather and blocks of rubber soaked in tar and packed alternately in the groove. If the working tension is very great, however, the wood filling is to be preferred, as in the case of long-distance transmissions where the rope makes two or more laps about the driving and driven sheaves, and is run at a comparatively slow speed. In such cases, instead of making two or more laps about ordinary sheaves or drums, it is sometimes more desirable, especially where space is limited, to use grip wheels, such as illustrated in Fig. 211. The rim, it will be observed, is fitted with a continuous series of steel jaws, which bite the rope by reason of the pressure of the same against them, but as soon as relieved of this pressure they open readily, offering no resistance to the egress of the rope.

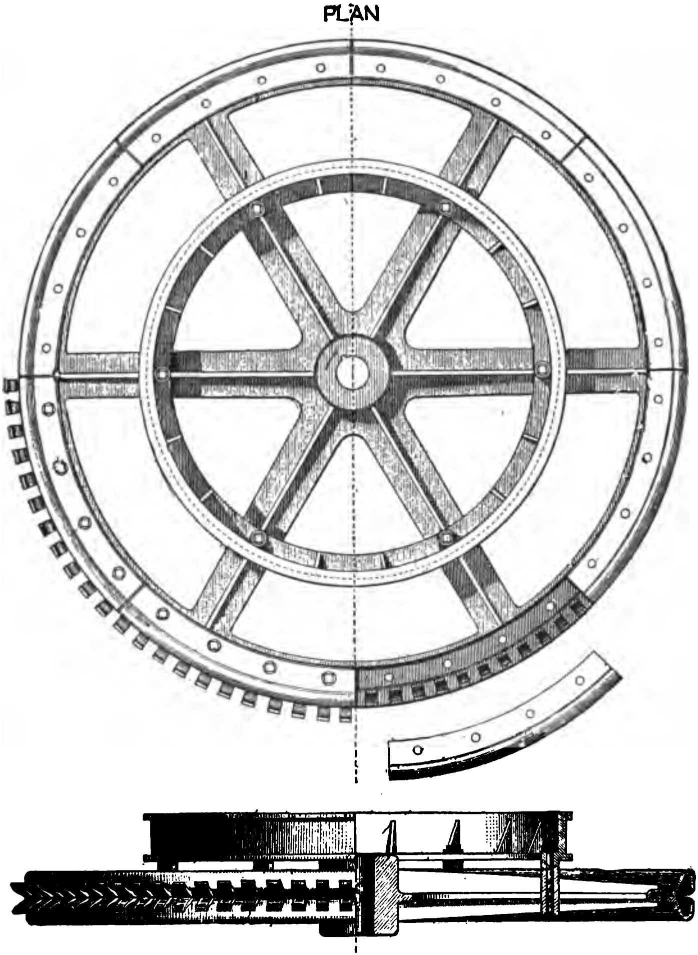


Fig. 211.

It frequently happens that it is impracticable to use sheaves corresponding to the maximum safe tension of the rope, in which case smaller ones may be used, but it will be understood of course that the wear of the rope will be more rapid.

Transmission sheaves should be well balanced; otherwise uneven wear will result in the bearings, and also in the filling, causing the rope to sway violently. If the splice is poorly made, the filling roughly inserted, or the sheaves bored untrue, similar irregularities in motion will result. It should be borne in mind that no pains should be spared at the outset to secure the careful alignment and equal balance of the sheaves, on account of the high velocities at which they are run.

LIMITS OF SPAN.—On spans of less than about sixty feet, it is impossible to splice the rope to such a degree of nicety as to give exactly the required deflection, and as the rope is further subject to a certain amount of stretch, it becomes necessary in such cases to apply mechanical means for producing the proper tension in order to avoid frequent splicing which is very objectionable; but care should always be exercised in using such tightening devices, that they do not become the means, in unskilled hands, of overstraining the rope. The rope also is more sensitive to every irregularity in the sheaves and the fluctuations in the amount of power transmitted, and is apt to sway to such an extent beyond the narrow limits of the required deflections as to cause a jerking motion, which is very injurious. For this reason on very short spans it is found desirable to use a considerably heavier rope than what is actually required to transmit the power; or in other words, instead of a seven-wire rope corresponding to the conditions of maximum tension, it is better to use a nineteen-wire rope of the same size wires, and to run this under a tension considerably below the maximum. In this way is obtained the advantages of increased weight and less stretch without having to use larger sheaves, while the wear will be greater in proportion to the increased surface.

In determining the maximum limit of span, the contour of the ground, and the available height of the terminal sheaves must be taken into consideration. It is customary to transmit the power through the lower portion of the rope, as in this case the greatest deflection in this portion occurs when the rope is at rest. When running, the lower portion rises and the upper portion drops, thus enabling obstructions to be avoided which otherwise would have to be removed, or make it necessary to erect very high towers. The maximum limit of span in this case is determined by the maximum deflections that may be given to the upper portion of the rope when running, which for sheaves of 10 feet diameter is about 600 feet.

Much greater spans than this, however, are practicable where the contour of the ground is such that the upper portion of the rope may be the driver, and there is nothing to interfere with proper deflection of the lower portion, as for instance in crossing a ravine. Some very long transmissions of power have been effected in this way without an intervening support, one at Lockport, N. Y., having a clear span of 1,700 feet.

LONG-DISTANCE TRANSMISSIONS.—When the distance exceeds the limit for a clear span, intermediate supporting sheaves are used, with plain grooves (not filled), the spacing and size of which will be governed by the contour of the ground and the special conditions involved. The size will be determined by the angle of the bend. If the curvature due to this angle and the working tension, regardless of the size of the sheaves, as determined by the table page 22, is less than that of the minimum sheave (see table page 25) the supporting sheave should not be smaller than such minimum sheave, but if the curvature is greater a smaller sheave may be used, and in this case the consideration governing the size will be the wear due to the running of the rope over the sheave, which will be greater of course in proportion to the smaller size. The same remarks will apply to horizontal bends, in which case horizontal deflecting sheaves are required with supporting sheaves on each side of the angle.

In very long transmissions of power, requiring numerous intermediate supports, it is impracticable to run the rope at the high speeds maintained in "flying transmissions." A greater transmitting force is therefore necessary, which is obtained by lapping it several times about a pair of grooved drums at each end, or about a number of sheaves arranged in pairs in such manner that the rope makes a half-lap on each, and a final half-lap at one end about a sheave on a take-up, or counter-weighted carriage, which maintains the necessary tension in the slack portion.

Cable railways and wire rope tramways may be considered as long-distance transmissions of power, in which the load, instead of being concentrated at one terminal station, is distributed over the entire line.

There is a serious objection to numerous laps about solid-grooved drums, on account of the irregular wear of the grooves, which produces an undue stress in the rope that quickly destroys it, to say nothing of the great strain on the shafts; but we are prepared to furnish sheaves or drums especially designed to overcome this difficulty.

INCLINED TRANSMISSIONS.—When the terminal sheaves are not on the same elevation, the tension at the upper sheave will be greater than that at the lower, but this difference is a function of the weight of the rope only, and so slight in most cases that it may be ignored. The span to be considered is the horizontal distance between the sheaves, and the principles governing the limits of span will hold good in this case, so that for very steep inclinations it becomes necessary to resort to tightening devices for maintaining the requisite tensions in the rope. The limiting case of inclined transmissions occurs when one sheave is directly above the other. The rope in this case has nothing to do with the pressure on the lower sheave, while the upper sheave is subject only to its weight, which is usually so insignificant that it may be neglected altogether, and on vertical transmissions, therefore, mechanical tension is an absolute necessity.

DIRECTIONS FOR SPLICING.

The following directions for splicing the rope may be found useful, but, as a rule it is desirable to employ an expert to do this, since it requires considerable skill to splice a wire rope well, and to one unfamiliar with the method of procedure, printed directions are of little value:

FIRST.—Clamps are applied to the rope sufficiently far back from the ends to allow plenty of room for the splice, and the men to operate in. The two ends are then drawn together by means of blocks and tackle, until they overlap each other for a space of twenty to thirty feet, according to the size of the rope. At a point from each end midway of the lap, the rope must be bound with a good serving of No. 20 or No. 18 annealed wire. The serving at the extreme ends is then cut off, the strands uncoiled to the new serving, and the hemp cores also cut off so as to abut when the open bunches of strands are brought together, and the opposite strands interlaced regularly with each other, presenting the appearance, as near as can be shown, in Fig. 212. The serving *x* is then cut off, and the strands 2, 3, 4, 5 and 6 bent back out of the way, and tied temporarily to the rope.

SECOND.—Unlay any strand *a*, and follow this up with the free strand 1 of the other end, laying it tightly into the open groove left upon unwinding *a*, making the twist of the strand agree exactly with the lay of the open groove, until all but 12 or 18 inches of 1 is laid in,

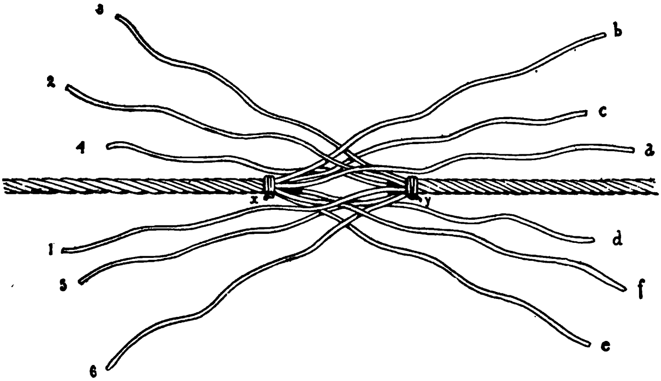


Fig. 212.

when *a* is cut off to within the same distance of the rope (see Fig. 213), and (excepting rope of Lang-lay) passed under 1, leaving the ends projecting while the other strands are laid in. Some tie these ends for the time being, although this is not essential.

THIRD.—Cut off the serving *y* and unlay a strand 6 of the opposite end, following up with the strand *f*, and laying it into the open groove as before, treating it precisely as in the first instance. Next, pursue the same course with *b* and 2, stopping, however, at a distance from the first ends of four to five feet, so as to leave a space of about a foot between the ends when finally tucked in. Next, do the same with *e* and 5, then *c* and 3, and finally *d* and 4, until all of the strands are laid in, with the respective ends projecting, as shown in Fig. 213.

FOURTH.—The next thing is to tuck in the ends, and this is where the skill comes in. *Before doing this, care should be observed to see that the spliced portion of the rope is perfectly limp, or free of tension, otherwise this operation cannot be well performed.* That portion of the rope where the ends are to be tucked in must first be untwisted, for which purpose special lever clamps are provided made of hard wood, two of which are applied, one on each side of the projecting ends. By turning these clamps in opposite directions, the strands are separated, presenting the open appearance shown in Figs. 214 and 215, disclosing the core. Without such clamps, the ropes may be untwisted by wrapping either side in opposite directions with a short piece of hemp rope laid double, using sticks passed through the end loops to turn with. If a vise is available it will be more convenient to secure one side by this means, in which case but one clamp or rope sling and stick, as the case may be, will be required. The core is then cut, and pulled out on the side corresponding with the end to be tucked in, for a distance equal to the length of the end which is to replace it. A sharp knife is needed for this purpose. The end to be tucked in is then straightened. It is desirable, especially if the rope is composed of small wires, to tie the ends of the strands with soft twine or threads of jute yarn, in order to keep the wires well bunched. A marlin spike is then passed over *a* and under two of the strands, as shown in Fig. 214, when the core is cut off at the proper point, and by moving the spike along the rope spirally with the strands, the loose end *a* is passed into the core space and the spike withdrawn. [Fig. 215 shows the end partially laid in, after having cut off the core.] Then pull out the core on the other side, pass the marlin spike over 1 and under two strands as before, cut off the core, and tuck in the end 1 in precisely the same manner, after which the rope is twisted back again as tightly as possible, and the clamps or other appliances that may be used, are removed to the next pair of projecting ends. Any slight inequality in the symmetrical shape of the rope may be taken

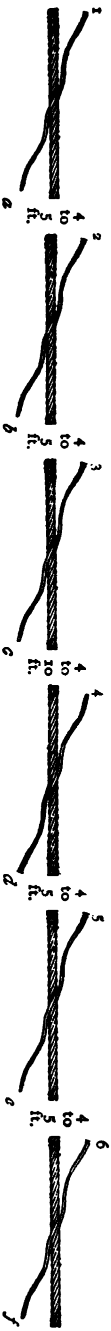


Fig. 213.

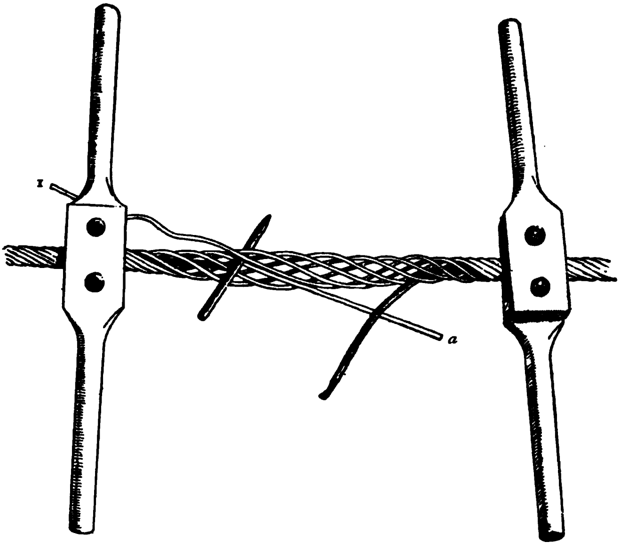


Fig. 214.

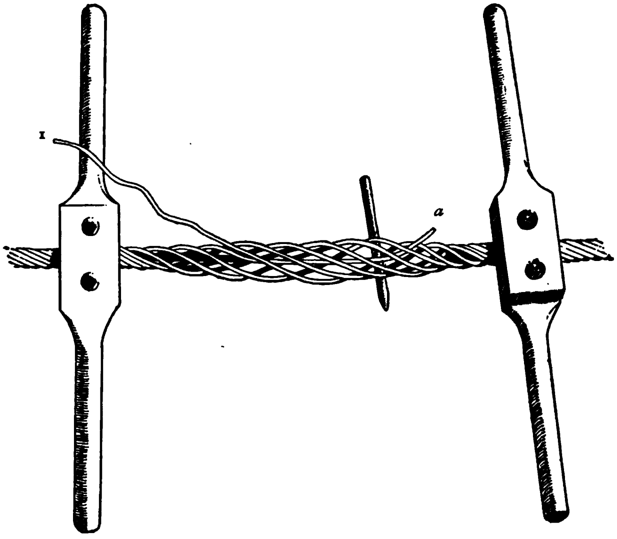


Fig. 215.

out by pounding with a wooden mallet. Some prefer to tuck in first all the ends projecting in one direction, and then the ends projecting the other way; it is immaterial in what order they are tucked in. If these directions are implicitly followed, the spliced portion of the rope will be of uniform diameter with other portions, and present a smooth and even appearance throughout. After running a day or two, the locality of the splice cannot be readily detected, and the rope will be quite as strong in this portion as any other.

SUSPENSION BRIDGES.

We manufacture wire cables and fittings expressly for suspension bridges, and are prepared to furnish complete equipments if desired, and also competent engineers to superintend their construction. Applications for estimates should state length of span between towers, width of roadway, character of traffic and maximum load. They should, if possible, be accompanied by a profile on the center line of the proposed structure, which line should extend back far enough to determine the location of the anchorages. The profile should show high and low water and the kind of material composing the banks and bed of the stream.

The tension at point of greatest deflection where cable becomes horizontal = load between points at which a horizontal line from top of lower tower intersects the cable multiplied by the distance between these points of intersection divided by eight times the deflection below this line.

The tension at either tower = square root of the sum of the squares of the horizontal tension so obtained, and of the load between the point of greatest deflection and the tower.

For a bridge in which the towers are on the same level, this becomes—

$$\text{Tension at center of span} = \frac{\text{Total load} \times \text{span}}{8 \times \text{deflection of cable.}}$$

$$\text{Tension at towers} = \sqrt{(\text{Tension at center})^2 + \left(\frac{\text{Total load}}{2}\right)^2}$$

$$\text{The length of catenary} = \text{span} + \frac{8 \times (\text{deflection of cable})^2}{3 \times \text{span.}}$$

WIRE CABLE FERRIES.

Wire cable ferries furnish a cheap means of transport across streams, in cases where the travel is not sufficient to justify the building of a bridge. The main cable is generally stretched over posts, A-frames, or towers on each bank, and firmly anchored to cribs, posts, trees, or stumps, as may be most expedient, although cases may arise, where durability is considered, that masonry anchorages will be found most advantageous. A good stout tree, if convenient, will afford, in most cases, as good an anchorage as can be desired. The boat is attached by means of a light chain or rope to a traveler or ferry block as it is sometimes known (Fig. 216), that runs along the main cable.

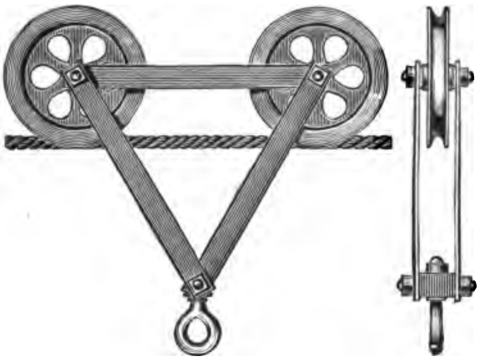
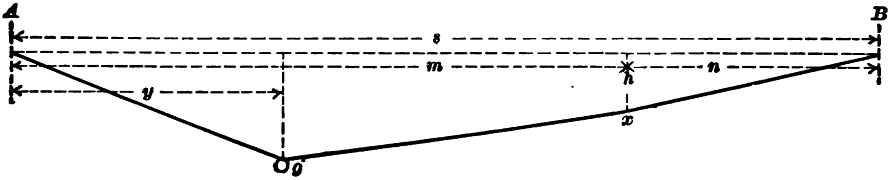


Fig. 216,
Ferry Traveler.

To operate the ferry, the boat is brought into a diagonal position with respect to the current, with the forward end pointing up stream; the current impinging at an angle against the side of the boat thus acts as a wedge power to move it across. To bring the boat back, the diagonal position is simply reversed. The boat is sometimes provided with boards on the side facing the current, which are lowered while crossing, so as to present a greater surface to the action of the water, the boards being hinged to the boat in such a way as to rise automatically upon approaching either bank.

The general formulæ on the following page will be found useful in determining the deflections corresponding to a given tension at all points of a suspended cable, either sustaining a concentrated load or unloaded, as the case may be, and also the tension corresponding to given deflections.

GENERAL FORMULÆ
FOR ESTIMATING THE DEFLECTION OF A WIRE CABLE CORRESPONDING TO A GIVEN TENSION.



Let $s =$ the distance between supports or Span *A B;*
m & $n =$ the arms into which the span is divided by a vertical through the required point of deflection x, m representing the arm corresponding to the loaded side;
$y =$ the horizontal distance from load to point of support corresponding with m;
$w =$ the weight of the rope per foot;
$g =$ the load;
$t =$ the tension;
and $h =$ the required deflection at any point x;
all measures being in feet and pounds.

Then for **DEFLECTION DUE TO ROPE ALONE,**

$$h = \frac{m\,n\,w}{2t} \text{ at } x, \text{ or } \frac{w\,s^2}{8t} \text{ at center of span.}$$

For **DEFLECTION DUE TO LOAD ALONE,**

$$h = \frac{g\,n\,y}{t\,s} \text{ at } x, \text{ or } \frac{g\,y}{2t} \text{ at center of span.}$$

$$\text{If } y = \tfrac{1}{2}s,\ h = \frac{g\,n}{2t} \text{ at } x, \text{ or } \frac{g\,s}{4t} \text{ at center of span.}$$

$$\text{If } y = m,\ h = \frac{g\,m\,n}{t\,s} \text{ at } x, \text{ or } \frac{g\,s}{4t} \text{ at center of span.}$$

For **TOTAL DEFLECTION,**

$$h = \frac{w\,m\,n\,s + 2\,g\,n\,y}{2ts} \text{ at } x, \text{ or } \frac{w\,s^2 + 4gy}{8t} \text{ at center of span.}$$

$$\text{If } y = \tfrac{1}{2}s,\ h = \frac{w\,m\,n + g\,n}{2t} \text{ at } x, \text{ or } \frac{w\,s^2 + 2gs}{8t} \text{ at center of span.}$$

$$\text{If } y = m,\ h = \frac{w\,m\,n\,s + 2gm\,n}{2ts} \text{ at } x, \text{ or } \frac{w\,s^2 + 2gs}{8t} \text{ at center of span.}$$

Note.—*If the tension is required for a given deflection, transpose* t *and* h *in above formulæ.*

WIRE ROPE FITTINGS.

The different methods of making attachments to wire ropes is a subject the importance of which is too often overlooked. Two distinct kinds of fittings are used: the Thimble, Figs. 217, 218, and 219; and the Socket, Figs. 220, to 223, inclusive. Of the former there are three methods of securing the thimbles: one (Fig. 217) is by simply bending the end of the rope around the thimble and fastening with clips; another (Fig. 218), by fraying out the wires a short distance at the ends, bending the rope around the thimble, laying the straightened wires snugly about the main portion of the rope, and finally serving or wrapping with suitable wire and bending back the extreme ends of the wires projecting beyond the portion wrapped; the third method (Fig. 219) is by interlocking the strands in the manner of a splice, and serving the whole with wire. The latter method is the most difficult attachment to make, but possesses the greatest strength, and if well done is as strong as the rope itself.

It is not always practicable to use thimbles, especially with large and unwieldy ropes, in which case attachments are made by means of sockets; and these are generally preferred for the smaller ropes also, on account of being easier to put on and neater in appearance. The ordinary socket (Figs. 220 and 221) consists of a funnel-shaped forging or steel casting with a loop or open prongs at the wide end, designated respectively as loop sockets and open sockets with keys. The rope is secured by fraying out the wires at the end for a distance equal to about twice the length of the socket aperture, observing the precaution first to serve the rope at the point where the straightened wires begin and the unfrayed-out strands terminate. Some of the wires are then trimmed off to shorter lengths, and all bent back upon themselves, hook-fashion, so that the resulting bunch will conform as near as possible to the conical shape of the socket. This bunch is then drawn into the socket, a conical plug rammed in the core, spreading the wires out tightly against the sides of the socket, and the whole finally cemented with molten Babbitt metal.

In the case of ropes made of large, stiff wires, the ends are simply straightened out and the interstices filled with narrow, tapering pins or wedges. Our Patent Locked-Coil Cable referred to on page 16 is

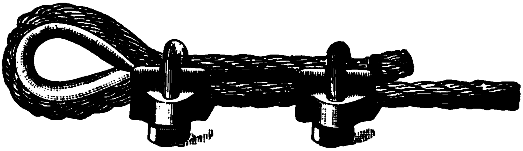


Fig. 217. The Crosby Wire Rope Clip.

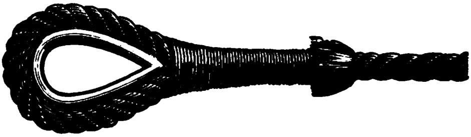


Fig. 218. Thimble.

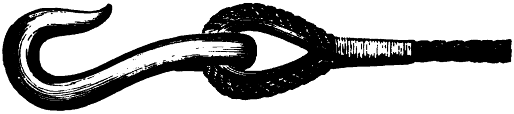


Fig. 219. Thimble and Hook.

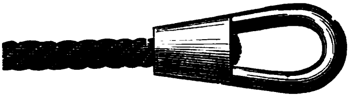


Fig. 220. Loop Socket.

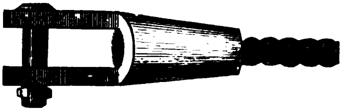


Fig. 221. Open Socket, with Key.

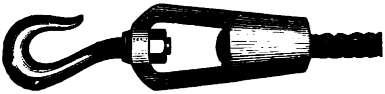


Fig. 222. Socket and Swivel Hook.

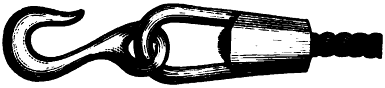


Fig. 223. Socket and Hook.

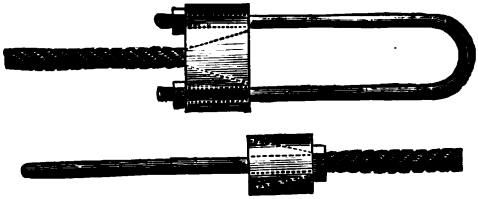


Fig. 224. Loop Stirrup.

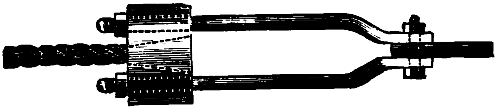


Fig. 225. Open Stirrup.

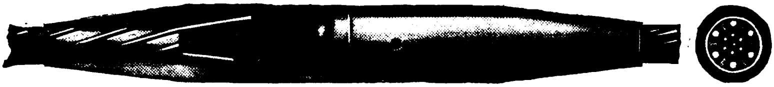


Fig. 226. Coupling for Patent Locked-coil Cable.

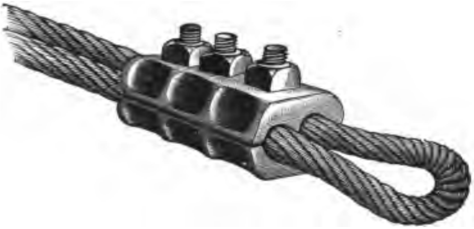


Fig. 227. Wire Rope Clamps.

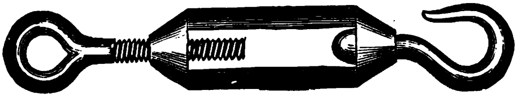


Fig. 228. Turn-buckle.

socketed in this way. Fig. 226 illustrates the patent coupling for joining the sections of this cable, and consists simply of two narrow cast-steel sockets, joined at the center by a plug with right and left-hand screw threads. The ends of the wires are spread apart in the funnel-shaped apertures, and the space between them filled with conical rings and narrow wedges made approximately to the shape of the interstices. The act of screwing up the plug drives in the rings and wedges uniformly, and with such pressure that no Babbitt metal is required.

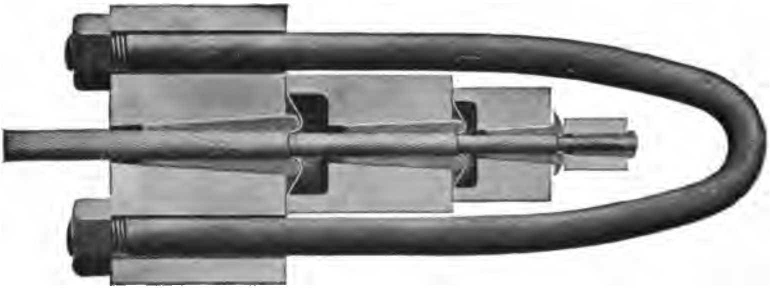


Fig. 229. Step Socket.

Attachments to the Patent Locked-Wire Rope (see page 14) are made by means of the socket illustrated in Fig. 229. This consists really of three or more sockets in steps, one behind the other, the larger for the outside wires, the following for the next larger, and so on down to the core. This style of socket can be relied upon in all cases to withstand any strain that the rope will safely bear.

Fig. 227 illustrates a clamp used on the larger sizes of ropes with special attachments, and Fig. 228 a turn-buckle, such as used in adjusting the tension of a wire rope.

WIRE ROPE SHEAVES AND TACKLE BLOCKS.

We manufacture iron or steel sheaves and tackle blocks of every description. To illustrate all the various kinds would require more space than is at our command.

Our transmission wheels, Fig. 210 (page 28), are furnished with the segmental rubber and leather or wood-filled rims as desired, the former filling being recommended for ordinary transmission of power, on account of its greater frictional adhesion, but for the terminal sheaves of wire rope tramways, where the pressure of the rope is very great, the wood filling has been found most satisfactory.

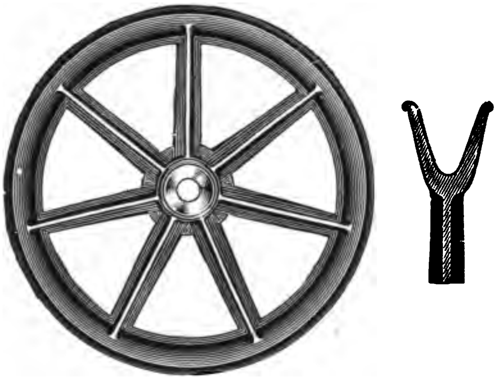


Fig. 230.
Hoisting Sheaves,
all sizes to 5 feet in diameter.

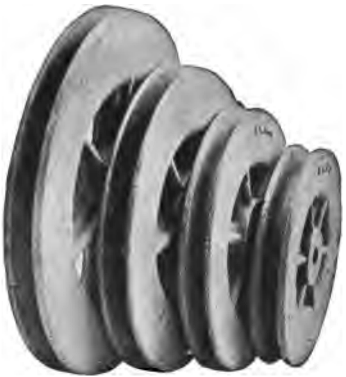
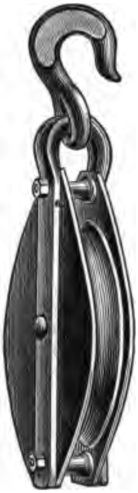


Fig. 231.
Derrick Sheaves,
12 to 54 inches in diameter over all.

Oval Shell with Link Hook.



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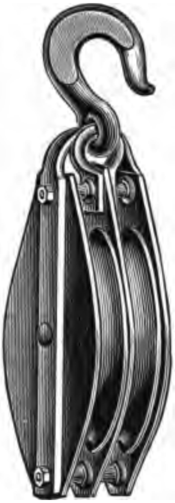
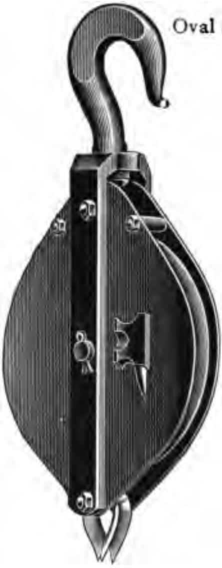


Double.

Oval Shell with Swivel Hook.



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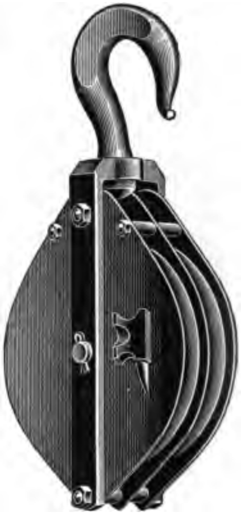
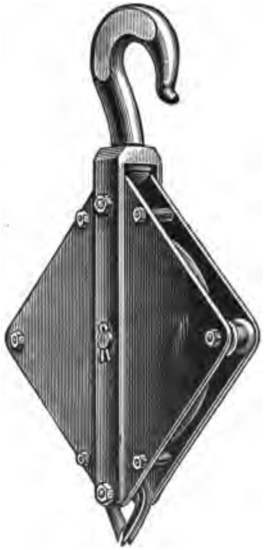


Double.

Diamond Shell with Swivel Hook.



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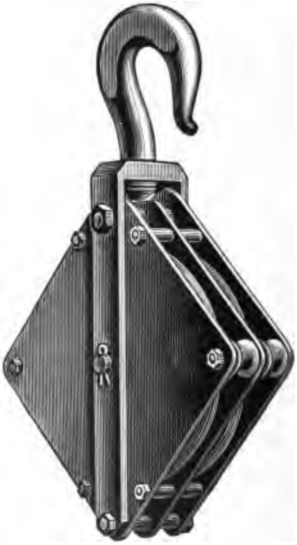
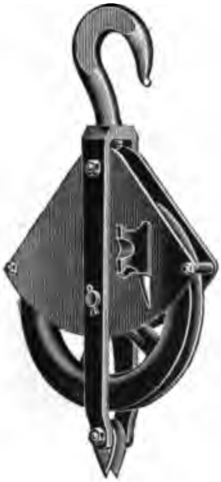


Double.

Heavy Pattern with Swivel Hook.



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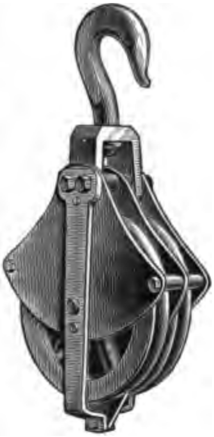
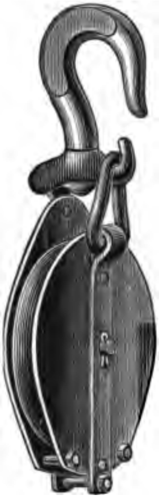
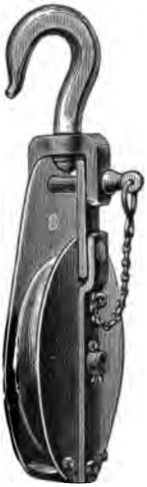


Double.

Drop Link.

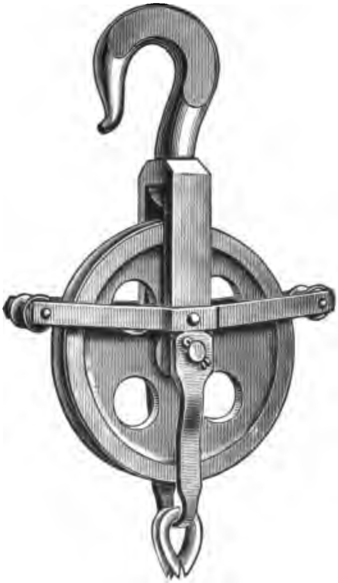


Shackle Pin.



Snatch Blocks.

Skeleton Guard with Swivel Hook.



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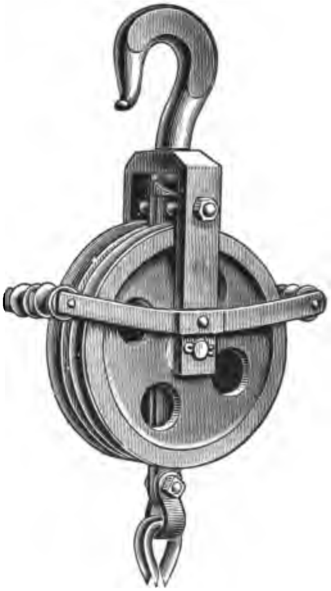
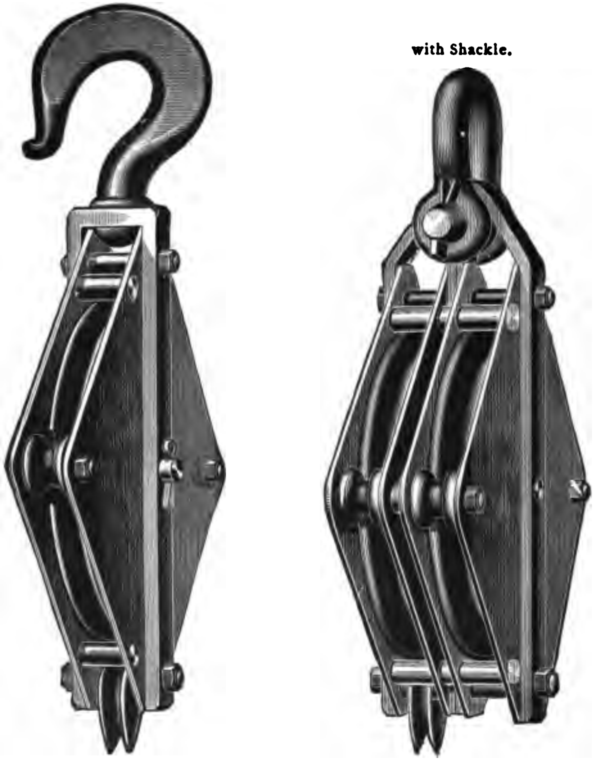


Double.

Gin Blocks.

Diamond Shell.



with Swivel Hook.

with Shackle.

Single.

Double.

Extra Heavy Blocks.

Our hoisting and derrick sheaves, Figs. 230 and 231, are designed for the heavy stresses that they have to withstand, the former being made with plain V grooves and ribbed arms, and the latter with solid webs and narrow flanges. The hubs are plain-bored, phosphor-bronze or metaline-bushed as desired.

Our tackle blocks, pages 44, 45 and 46, are made with one, two or more sheaves, according to the number of desired parts in the rope, the sheaves being grooved to fit the rope. We furnish them with hubs plain-bored, phosphor-bronze or metaline-bushed; with oval, diamond or sector-shaped shells, or skeleton guards; with link or swivel hooks; and with beckets or shackles. Our snatch blocks are made with drop links or shackle pins, as desired.

THINGS WORTH KNOWING ABOUT WIRE ROPE.

To obtain the weight per foot w, D representing the diameter of the rope in inches, we have:

For ordinary wire rope with hemp core, $w = 1.57\ D^2$
“ “ “ “ “ wire “ $w = 1.7\ D^2$
“ patent locked-wire rope, ... $w = 2.5\ D^2$
“ solid round bar, ... $w = 2.62\ D^2$

For a cable composed of straight wires, to obtain the number of wires n, D representing the diameter of the rope, and d the diameter of the individual wires, in inches, we have:

$$n = \frac{77\ D^2}{100\ d^2}$$

To obtain the length in feet L of wire rope in a coil, C representing the outside diameter, c the inside diameter, and W the width of the coil, and D the diameter of the rope, all in inches, we have:

$$L = \frac{W\,(C^2 - c^2)}{15.28\ d^2}$$

Good wear and proper service in a wire rope are indicated by the flattening of the outer wires, resulting eventually in their fracture. ***Fractured wires not worn or flattened indicate undue bending, abrasion, or poor material; don't condemn the rope until you ascertain which it is.***

For further particulars regarding the applications of wire rope, address, THE TRENTON IRON CO., Trenton, N. J.

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